HUMAN BIOLOGY

a record of research

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a record of research

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RESEARCH IN HUMAN GROWTH

1.

RESEARCH in human growth has attained a considerable age, and with it some degree of maturity. Today, nearly 200 years after the first longitudinal growth study (Scammon, '27) we are still acquiring a basic knowledge of the mechanisms and processes of growth in man.

Growth in general is not well understood.[1] Though easy to measure, and simple to demonstrate, why things grow is still a fundamental mystery. Little is known about growth at the cell level, still less about the nature of multi-cellular growth. More complicated aspects of growth spill over into the problem of form (Bonner, '52). The growth of a leaf is an analytic puzzle of itself; still more the growth of the morphologically simpler but structurally more complex fish (Thompson, '42). And with mammals, with vastly different growth rates for individual organs and tissues and with numerous growth-limiting systems, we need to investigate one process or one mechanism at a time, if we are to elucidate the nature of growth.

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[1] Count ('55) has called growth a "catchall" term. While many different processes modify or affect growth it is still possible to center attention on the phenomenon of growth itself.

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Dated ....

We know most about statural growth in man. It is admittedly a summation, and admittedly a special kind of growth, not quite an example of Scammon's "general" growth curve. But stature (or crown-heel length, or recumbent length) is simple to measure, and can be followed in the same subject from birth onward. By measuring from the sole of the foot to vertex, a whole range of phenomena have been discovered. Some are characteristic of all mammals, some are characteristic of man, while others are reflections of changes in the way of life, in nutritional knowledge, or in the management of "childhood" diseases.

We know far less about the growth of the body segments. Though segmental growth rates have been published for some populations (Kelly and Reynolds, '47, Meredith, '47, Anderson *et al.*, '56) the role of the long bones in the trend toward increasing stature is still unclear. We know rather little about the true growth of the skull and its components. Should we consider the bone or the suture? (*cf.* Baer, '54, Mednick and Washburn, '56). The face itself provides a particular problem, for it cannot be fragmented into growing components by conventional cephalometry. Tooth development, on the other hand, proves far more accessible to radiological investigation (Gleiser and Hunt, '55, Garn, Lewis and Shoemaker, '56) as does the ossification of the spine. The growth of individual muscle groups, known at present by dissection of laboratory material, is not beyond the scope of serial roentgenographic studies, and with the judicious use of contrast techniques, semi-longitudinal analysis of the growth of particular inner organs may prove practical.

Endocrine knowledge has reached the point where most students of growth speak knowingly of the growth-promoting and thyroid-stimulating pituitary hormones, of the protein anabolic hormones, and the cortical-stimulating hormones. Though they may not measure the neutral ketonic steroids, they are aware of their influences on the epiphysial plate. Moreover, measurements of the 17-ketosteroids is no longer a novelty. From testosterone administration, to monkeys (Van Wagenen and Hurme, '50), to developmentally retarded children (Sobel, *et al.*, '56), and to starvation victims, the influence of such steroids is becoming clear. The experimental approach may be impractical in most growth studies, but the research design can be organized so that hormonal effects can be brought into consideration (Talmers, '52).

Students of animal heredity have contributed magnificently to the genetics of growth. With the very practical purpose of selecting for meat, for rapid growth, or for convenient barnyard proportions, both their techniques and their findings bear closest watching (Hancock, '51, Barnicoat and Shoreland, '52, Shoreland *et al.*, '47). The question of parental size and its influence on the offspring, recalls Galton's investigations published in 1889, and his statistical device the "mid-parent." Selection for maximum muscle mass, a technique important to New Zealand sheep-raisers, suggests a kind of study that can be applied to selected matings in man. And techniques developed for the study of human physical growth have been taken over by geneticists specializing in hogs, cattle and sheep. Thus, when genes that control fattening, fleshing or axial growth are discovered for our domestic animals (*cf.* Dickerson, '54), the possibility of uncovering similar phenomena in human beings, through the use of the same techniques, looms near.

2.

The progress of most areas in science can be estimated first by counting journal articles, and then by enumerating textbooks. By this rule, human growth is growing right along. Though publications are dispersed among the medical, physiological and anthropological literature, the sum total has increased to the point where no yearly review can do justice to them all. We are as likely to find a "growth" article in the *Journal of Applied Physiology* as in *Growth*, in *Child Development* as in *Human Biology*, in the *Journal of Social and Preventive Medicine*, as in the *American Journal of Physical Anthropology*. And the number of general texts has increased impressively since "Growth" (Robbins *et al.*, '28) and "The Measurement of Man" (Harris *et al.*, '30). It is unfortunate that American readers do not have an opportunity to peruse De Toni's "L'accrescimento Umano" ('54), and Suarez' "Crecimiento" ('54), as they do Tanner's splendid "Growth at Adolescence" ('56).

Another rule for judging the progress of a science, is to enumerate those institutions where research is carried on, not just because of a lone investigator's interest, but because the particular area has become recognized. In this country we have at least 5 permanent, well established centers: Merrill-Palmer, Iowa Child Welfare Station, Denver Child Research, The Harvard Study, and the Fels (*cf.* Tanner, '48). Besides these, there are active studies at the Forsyth Dental Infirmary, the University of Oregon, the University of Louisville School of Medicine, and the new and important Philadelphia Study for Research in Child Growth. And abroad, a very large number of studies have been inaugurated—in London, Oxford, Paris, Brussels, and Helsinki. Nutritional studies at Iowa are paralleled by nutritional studies in Melbourne; major research is carried on in Guatemala, Uganda, and Capetown, while publications pour in from Japan, New Zealand, Holland, Italy and (in a torrent) from the busy Scandinavian countries.

Still another test is that of financial support. This is not an "exact" test, because research relating to children appeals to governments. Moreover, research grants often follow fashion. Devise a growth investigation that employs tranquilizers, and obtain funds by return mail! Yet, there are over two-dozen government and non-government agencies in the United States that stand ready to entertain applications in the field of human growth. These may be entered under the following categories: (1) Child Development, (2) Mental Health, (3) Maternal and Child Health, (4) Nutrition, (5) Radiation, (6) Dental Health, (7) Human Genetics, (8) Disaster Research, (9) Morale Studies, (10) Cancer Research, (11) Mental Deficiency and (12) Biometrics. To qualified applicants, funds are now available for laboratory construction, building, training of personnel, and education. Besides government, and the major philanthropies, growth research has been supported by fraternal orders, civic duty clubs, women's organizations, religious groups, and state affilliates of the large medical funds.

And finally, in evaluating the present status of growth research, consider where human growth is taught. It is not in the medical schools, where a meagre fraction of the lectures on Pediatrics are devoted to the elements of growth,[2] nor in those few colleges where "human growth" is offered as a part of biology, but in the departments of Psychology, Education and Child Development, that the most attention is currently given to the phenomenon of growth in man. Education majors are often given more information on growth (some of it inaccurate) than anthropology majors or biology concentrators. The growing field of Child Development, replacing Home Economics on many campuses, usually includes a course on "growth": the new area of Family Studies makes growth and development a major part. And to fill the need for teachers, some graduate schools of education grant a Ph. D. or Ed. D. degree in *Growth*, a degree that has premium value as state-supported schools of education expand.

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[2] The medical schools feel that growth is adequately presented in first-year anatomy, and in lectures on pediatrics. This claim may be viewed with doubt.

3.

Today's studies in human growth tend to differ from those of yesteryear in being increasingly problem-oriented, theory-conscious, and biologically relevant. The purely normative, purely applied study, is being taken over by the medical profession, as is entirely proper. The purely descriptive study, while still here, tends to be so much more conscious of theory and mechanisms as to have an entirely different flavor. And while height and weight are still included in growth studies, these two are increasingly employed as reference standards, rather than as prime variables.

At the same time, studies in human growth are subjected to constant reappraisals both from within and without. The emphasis is less on "how to" and more on "why." Ten years ago the program at the Fels Research Institute was appraised by an advisory board, selected for that particular purpose. More recently the studies at the Denever Child Research Council were evaluated and within the past year a team from the University of Pittsburgh studied longitudinal studies and appraised them (Kodlin and Thompson, '56). These appraisals and evaluations, coupled with Tanner's earlier admonitions (Tanner, '51, '52) have brought a "new look," a new approach to strategy, a commendable degree of self-criticism. Why collect growth data against some indefinite date in the future? Why use the longitudinal approach for problems essentially cross-sectional? Why pursue a problem when that problem no longer continues to exist?[3]

As a result it would appear that there has been a healthy shift of attention from the approach to the problem. The very approach of the conventional longitudinal study (with its emphasis on well-off, healthy children) resulted in ignoring some very real problems of growth. The under-privileged child can contribute information on growth, so can the victim of strife or pestilence. World events, in recent years, have brought about a host of "natural experiments." In the siege of Leningrad (Antonov, '47) and the terrible winter in Rotterdam (Smith, '47), the effect of maternal undernutrition has become evident. The capture and relocation of civilian populations has contributed important information for growth research (*cf.* Garn and Moorrees, '52). And the changes in diet that followed the German occupation of Scandinavia, not only posed a major investigative problem, but the findings on dental health (Toverud, '56) may prove more revealing than a decade of lactobaccilus counts and Stannous fluoride experiments on well-to-do Americans in Eugene, Oregon, or Trenton, New Jersey.

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[3] Both Sontag ('55), and A. L. Washburn ('56) have commented on the optimistic "shotgun" approach that characterized the early days of longitudinal studies (*cf.* Kodlin and Thompson, '56). Sontag, in particular, calls attention to the fact that problems change too. What is a burning problem of today, may appear passé a decade hence.

4.

Inevitably, growth studies have become more technological. Where once a yardstick and a beam-scale constituted the sum total of equipment, a vastly greater inventory of tools and techniques seems necessary today. No one study can afford all of them, or even an appreciable fraction of them. This constitutes an advantage in itself, a guarantee against sameness, the "me too" approach to research. Before purchasing a direct-writing electrocardiograph, an electromyelograph, or a recording dermal thermometer, the research worker needs to consider his overall plan and the relevance of the instruments to the purposes of his research.

Our knowledge of growth in the living has been furthered much by radiography. Bone lengths, muscle size, fat thickness, heart size, dental formation, the growth of the cranium—all of these are best investigated through the medium of the x-ray film. And the possibilities of radiology have barely been explored. Tomography ,by way of example, has rarely been used in growth studies, and Paatero's new system of pantomography (Paatero, '54) would seem to open new avenues for research. Since the high tension side of an x-ray unit can be triggered by a low-voltage signal, it is possible to "freeze" the heart, or a muscle complex in action. And by metallic staining, radiography can now overlap with histology (O'Rahilly and Meyer, '56).

There is growing awareness of radiation hazards, and the long-term consequences of radiation far below the lethal dose (*cf.* Miller, '56). Inevitably, this awareness will limit the extent of radiation used in growth studies. But it need not preclude the intelligent use of radiography: "shotgun" research has no basis for existing, there is no need to try x-rays of this and x-rays of that. There is no need to use more penetrating radiation than is absolutely necessary. "No-screen" film (sometimes used in taking carpal x-rays) requires *ten times more exposure* than does fast film with intensifying screens. New "lightening" screens can halve the total exposure again. Forced development yields an increased density on the film, thus allowing a still lower exposure to x-radiation. Besides, more attention can be given to shielding. Why expose most of the body, to obtain a radiograph of a limb, when an adjustable "Videx" or Phillips cone can limit radiation to the exact area required? Why encounter even the very low risk of mutations, when a simple lead-rubber shield can limit gonadal radiation to 0.02 R or less for an entire series of soft-tissue radiographs?

Interestingly, effective use of photography has rarely been made in growth studies. While photographs have been taken and published as examples of this or that, the fact that photography is a powerful tool, has been lost to sight, except perhaps to the followers of Sheldon. Yet, as Gavan, Washburn and Lewis ('52) demonstrated, a photograph can serve as substitute for the subject. Photographic anthropometry is quite practical with ordinary equipment or the "Photometric" camera. Photographs can yield measurements of small details, and can afford quantitative data on sexual maturation (*cf.* Garn, '52). Surface area can be determined by planimetry of shadowgrams or specially-posed photographs, as Benedict showed forty years ago, and Geoghegan ('53) more recently. And for the study of the superficial blood vessels, infra-red photographs are better than the subjects, as the illustrations published by Abramson and Glazier ('56) clearly show.

While we may pride ourselves in going "beneath the surface" with skinfold calipers and deep radiography, there is still much to be learned from purely superficial studies. The pigments of living human skin bear considerable investigation (*cf.* Lasker, '54); they undergo profound changes during sexual maturation (Garn, Selby and Crawford, '56). Besides, the sebaceous secretions of the skin, the activity of apocrine and holocrine glands, and the behavior of labelled hair follicles remain to be studied throughout the life span.

5.

I have left until last mathematical and graphical analyses of growth in man. No one can doubt the potential contribution of mathematical analyses to the understanding of growth. At the same time, there is no great discovery in proving that a curve can be fitted, nor in demonstrating that some transform effectively straightens a curvilinear relationship. Such work constitutes a necessary prerequisite for further studies and is not an end-point of itself.

Moreover, there is a positive danger in generalizing from curves.

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The "curve of population growth" works for man in the mass, but applies to not one individual child. Robertson argued that the "adolescent spurt" was an inevitable characteristic of an autocatylitic monomolecular reaction: today we know the hormonal basis of this very spurt. The log/log plot appears to fit a variety of length/length data, but the same data often follow a straight line on simple linear coordinates.

Curves, curve-fitting, points of inflection and differences in the value of k are meaningful when they are related to biology, or when they bear upon or suggest new biological mechanisms. Huxley's hypothetical Martian, given age-size data for individual human beings, would correctly infer some important change occurring shortly after the first decade, and a second change sometime in the second decade. That selfsame erudite Martian, would correctly infer (from the shifting value of k) that the growth of the human embryo changes abruptly at the end of the first trimester. Both facts would be new to the Martian: they are not new to us!

This observation applies to many of the mathematical analyses of growth that can be found in the literature today. It is not that the logistic curve, or Courtis "personalized" double-log cycles, or neo-Huxleyan allometry are wrong, it is that the applications are rarely rooted in biology, and still more rarely relate to the biology of growth.

6.

What to say about research in human growth? I have tried twice, once by myself (Garn, '56b) and once with company (Sontag and Garn, '54), to review a part of the literature. Krogman's recent compendium (Krogman, '56), absolves me from part of that task now. I have attempted here to indicate some of the less obvious things about human growth studies, to highlight some of today's work and to suggest some of tomorrow's findings.

The measurement of human growth has not changed radically since "The Measurement of Man" (Harris *et al.*, '30), and "Growth" (Robbins *et al.*, '28). Even with tricoordinate anthropometry, the photometric camera, and teleoroentgenogrammetry—a horrid word—our knowledge of the growth phenomenon is not notably different from what Scammon knew.

I cannot discern the existence of a New Human Growth, a developmental twin to Washburn's "New Physical Anthropology." Today's most intriguing problems in growth are contemporary with Montbeillard, Buffon and Galton, Hrdlička, Todd and Scammon. We still want to know why we grow, and why we grow as we do grow.

I have been fortunate in having had a chance to investigate phenomena accessible only through biochemistry, roentgenology, or spectrophotometry. Yet the serum lipids, the development of the permanent molars, or the pigments of living human skin do not contribute to the knowledge of growth unless they indicate how we grow, why we grow, how size and form are attained, or how any of these can be modified. The problem of growth remains the foremost problem in research relating to growth. To coin a cliche, the proper study of growth research is growth.

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STANLEY MARION GARN

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GROWTH OF SOUTH AFRICAN BABIES IN THE FIRST YEAR OF LIFE [1]

BY EVA J. SALBER [2]

This paper is a report of growth of European, Colored, Bantu and Indian babies in the first year of life, as measured by their weights from two to 52 weeks.

MATERIAL USED AND METHOD OF ANALYSIS

This is a mixed longitudinal and cross-sectional study, since—although the same babies are followed over a year,—not all the babies attended every week, and the sample and number of babies at each week therefore varies.

Data were extracted from the records of:

2096 European infants:	1116 boys,	980 girls.
1303 Bantu infants:	628 boys,	675 girls.
579 Colored infants:	284 boys,	295 girls.
509 Indian infants:	259 boys,	250 girls.

All available records from the Durban Municipal Child Welfare Clinics from 1948—1951 were used, but multiple births and records of infants who had attended less than 6 times in their first year were excluded. The data extracted consisted of race, sex, birth rank, birth weight where available, dates of attendance and weights at those attendances from two to 52 weeks. Since in the non-European groups the birth weight was often not recorded and a certain number of premature babies must inadvertently have been included in the records used, premature babies in the European group were deliberately included so as to make the records comparable.

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[1] This paper forms part of the material of an M. D. thesis, University of Cape Town.

[2] Formerly of Department of Medicine, University of Cape Town and of the Institute of Family and Community Health, Durban.

In the first instance, the growth curves and rates of growth were compared in the four racial groups, for boys and girls separately. Mean weights and standard deviations were worked out for each week from two to 52 weeks. The figures were then smoothed by taking a running average over 5 weeks, for example the 8 week figure was an average of the mean weights at 6, 7, 8, 9 and 10 weeks. At each end of the scale (2–3 and 51–52 weeks) this was not possible, so the third week weight and the 51st week weight were calculated on an average of three weeks only (2, 3, 4 and 50, 51, 52) while the second week and the 52nd week showed the actual weights for that week only. These figures were used for the graphs and also for calculating increments of growth.

The rates of growth of the babies of the four racial groups were calculated at four week intervals during the first year, by successive substraction of mean weights at those age levels, and this was expressed also as the number of ounces gained per week.

RESULTS

Tables 1–4 show the mean weights from two to 52 weeks for each racial group, boys and girls separately. First born (rank 1) and subsequently born (rank 2 +) and combined. Charts 1(a) and (b) are a comparison of the growth curves of European, Colored, Bantu and Indian babies during the first year of life, for boys and girls separately, all ranks combined and irrespective of birth weights.

Boys

(1) At the beginning of the year European babies are the heaviest, Indian babies the lightest, and the Colored and Bantu babies occupy an intermediate position with the Colored slightly higher than the Bantu. At the end of the year, the European babies are still the heaviest and the Indian the lightest, but the Colored and Bantu, although still occupying an intermediate position have reversed their places, the Bantu now being heavier than the Colored.

(2) At three weeks the European and Colored weights are the same, 8.40 lbs and 8.42 lbs, while the Bantu are slightly less at 8.22 lbs and the Indian about a pound lower at 7.33 lbs. At 51 weeks the gap has widened considerably with Europeans 22.53 lbs and the difference between European and Bantu being 1.59 lbs, European and Colored 2.17 lbs, and European and Indian 4.28 lbs. Fifty-one weeks has been chosen rather that 52 weeks because of a peculiar spurt shown by the Bantu and

TABLE 1

Weights of European infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2	7.85	7.25	8.06	7.74	7.98	7.55
3(2–4)	8.23	7.77	8.51	8.17	8.40	8.01
4(2–6)	8.66	8.22	8.96	8.58	8.83	8.43
5(3–7)	9.08	8.65	9.39	8.99	9.26	8.84
6(4–8)	9.50	9.08	9.81	9.40	9.68	9.26
7(5–9)	9.92	9.49	10.24	9.76	10.10	9.64
8(6–10)	10.34	9.88	10.63	10.11	10.50	10.01
9(7–11)	10.74	10.26	11.05	10.47	10.91	10.37
10(8–12)	11.12	10.65	11.45	10.85	11.30	10.76
11(9–13)	11.53	10.99	11.82	11.18	11.69	11.09
12(10–14)	11.94	11.36	12.22	11.55	12.09	11.46
13(11–15)	12.36	11.71	12.59	11.92	12.49	11.83
14(12–16)	12.75	12.05	12.97	12.28	12.87	12.17
15(13–17)	13.16	12.40	13.36	12.60	13.27	12.51
16(14–18)	13.56	12.77	13.75	12.94	13.66	12.86
17(15–19)	13.92	13.11	14.12	13.26	14.02	13.19
18(16–20)	14.26	13.46	14.48	13.56	14.38	13.51
19(17–21)	14.62	13.81	14.83	13.86	14.73	13.84
20(18–22)	14.97	14.13	15.18	14.15	15.08	14.14
21(19–23)	15.26	14.45	15.51	14.45	15.39	14.45
22(20–24)	15.61	14.78	15.79	14.69	15.70	14.73
23(21–25)	15.90	15.07	16.10	14.98	16.00	15.02
24(22–26)	16.22	15.38	16.40	15.26	16.31	15.32
25(23–27)	16.49	15.66	16.69	15.50	16.59	15.58
26(24–28)	16.79	15.94	16.97	15.76	16.88	15.85
27(25–29)	17.03	16.17	17.29	16.10	17.17	16.14
28(26–30)	17.33	16.47	17.55	16.35	17.45	16.41
29(27–31)	17.59	16.73	17.80	16.57	17.70	16.65
30(28–32)	17.88	17.00	18.07	16.82	17.99	16.91
31(29–33)	18.14	17.25	18.31	17.07	18.24	17.16
32(30–34)	18.43	17.51	18.52	17.25	18.48	17.38
33(31–35)	18.65	17.70	18.80	17.46	18.73	17.58
34(32–36)	18.86	17.93	19.02	17.72	18.95	17.82
35(33–37)	19.09	18.21	19.25	17.97	19.17	18.08
36(34–38)	19.32	18.46	19.48	18.21	19.40	18.33
37(35–39)	19.54	18.70	19.74	18.44	19.65	18.57
38(36–40)	19.77	18.95	19.92	18.72	19.85	18.84
39(37–41)	20.05	19.19	20.20	18.94	20.13	19.07
40(38–42)	20.27	19.40	20.37	19.07	20.32	19.24
41(39–43)	20.51	19.59	20.56	19.30	20.54	19.44
42(40–44)	20.73	19.76	20.68	19.44	20.70	19.60
43(41–45)	20.99	19.97	20.93	19.58	20.96	19.78
44(42–46)	21.19	20.14	21.05	19.66	21.12	19.90
45(43–47)	21.44	20.32	21.16	19.90	21.29	20.10
46(44–48)	21.61	20.45	21.35	19.98	21.47	20.21
47(45–49)	21.89	20.66	21.53	20.19	21.70	20.41
48(46–50)	22.12	20.82	21.65	20.30	21.86	20.55
49(47–51)	22.37	21.03	21.85	20.50	22.09	20.76
50(48–52)	22.56	21.22	22.09	20.71	22.30	20.96
51(50–52)	22.80	21.48	22.31	20.88	22.53	21.17
52	22.94	21.72	22.47	21.34	22.67	21.52

TABLE 2

Weights of Colored infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2			7.99	7.96	7.89	7.76
3 (2–4)	7.90	7.56	8.58	8.19	8.42	8.02
4 (2–6)	8.42	8.10	9.10	8.57	8.90	8.43
5 (3–7)	8.85	8.56	9.60	8.93	9.38	8.81
6 (4–8)	9.32	9.01	10.07	9.33	9.84	9.22
7 (5–9)	9.75	9.40	10.52	9.76	10.29	9.64
8 (6–10)	10.22	9.78	10.94	10.15	10.72	10.03
9 (7–11)	10.70	10.16	11.31	10.56	11.13	10.43
10 (8–12)	11.11	10.54	11.75	10.91	11.56	10.79
11 (9–13)	11.45	10.90	12.11	11.22	11.92	11.12
12 (10–14)	11.79	11.29	12.46	11.51	12.28	11.44
13 (11–15)	12.13	11.56	12.83	11.80	12.63	11.72
14 (12–16)	12.48	11.93	13.05	12.13	12.88	12.06
15 (13–17)	12.84	12.21	13.24	12.34	13.12	12.30
16 (14–18)	13.26	12.51	13.53	12.62	13.44	12.58
17 (15–19)	13.64	12.89	13.81	12.88	13.74	12.89
18 (16–20)	14.07	13.35	14.05	13.14	14.03	13.22
19 (17–21)	14.37	13.59	14.52	13.42	14.46	13.47
20 (18–22)	14.70	13.89	14.82	13.76	14.78	13.80
21 (19–23)	15.00	14.37	15.14	14.13	15.09	14.16
22 (20–24)	15.24	14.49	15.43	14.35	15.35	14.34
23 (21–25)	15.36	14.63	15.74	14.52	15.61	14.49
24 (22–26)	15.54	14.89	15.89	14.69	15.77	14.70
25 (23–27)	15.69	15.19	16.18	14.92	16.03	14.96
26 (24–28)	15.76	15.14	16.47	15.08	16.33	15.09
27 (25–29)	16.00	15.42	16.68	15.28	16.54	15.37
28 (26–30)		15.25	16.89	15.66	16.73	15.73
29 (27–31)			17.16	15.79	17.03	15.90
30 (28–32)			17.50	16.02	17.31	16.09
31 (29–33)			17.63	16.00	17.41	16.20
32 (30–34)			17.86	16.16	17.67	16.35
33 (31–35)			18.05	16.32	17.93	16.44
34 (32–36)			18.04	16.61	18.02	16.70
35 (33–37)			18.16	16.63	18.17	16.80
36 (34–38)			18.30	16.82	18.34	16.98
37 (35–39)			18.51	17.04	18.51	17.20
38 (36–40)			18.59	17.10	18.62	17.39
39 (37–41)			18.88	17.04	18.81	17.47
40 (38–42)			18.88	17.28	18.86	17.80
41 (39–43)			19.07	17.69	18.99	18.10
42 (40–44)			19.21	17.72	19.15	18.17
43 (41–45)			19.20	17.90	19.12	18.29
44 (42–46)			19.27	18.10	19.24	18.43
45 (43–47)			19.26	18.01	19.28	18.31
46 (44–48)			19.23	17.92	19.39	18.33
47 (45–49)			19.29	18.14	19.47	18.50
48 (46–50)			19.55	18.11	19.74	18.50
49 (47–51)			19.72	18.34	19.86	18.80
50 (48–52)			20.17	18.60	20.23	19.02
51 (50–52)			20.41	18.77	20.36	19.21
52			21.05	18.81	20.94	19.22

TABLE 3

Weights of Bantu infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2	7.28	6.75	7.71	7.44	7.60	7.29
3(2–4)	7.83	7.44	8.34	8.05	8.22	7.90
4(2–6)	8.36	8.02	8.97	8.60	8.80	8.46
5(3–7)	8.93	8.58	9.55	9.14	9.38	9.01
6(4–8)	9.58	9.13	10.14	9.65	9.98	9.54
7(5–9)	10.18	9.67	10.71	10.12	10.55	10.03
8(6–10)	10.83	10.21	11.26	10.58	11.13	10.51
9(7–11)	11.48	10.68	11.76	11.02	11.67	10.96
10(8–12)	12.01	11.21	12.21	11.48	12.15	11.43
11(9–13)	12.46	11.58	12.67	11.88	12.60	11.82
12(10–14)	12.86	12.05	13.09	12.30	13.05	12.24
13(11–15)	13.20	12.46	13.46	12.68	13.42	12.63
14(12–16)	13.64	12.82	13.86	13.08	13.84	13.02
15(13–17)	14.03	13.08	14.17	13.38	14.17	13.31
16(14–18)	14.44	13.49	14.53	13.75	14.54	13.69
17(15–19)	14.87	13.74	14.81	14.03	14.83	13.97
18(16–20)	15.32	14.07	15.09	14.30	15.15	14.25
19(17–21)	15.63	14.27	15.34	14.50	15.42	14.46
20(18–22)	15.98	14.57	15.68	14.79	15.77	14.74
21(19–23)	16.19	14.86	15.86	15.03	15.96	15.00
22(20–24)	16.47	15.10	16.12	15.34	16.22	15.29
23(21–25)	16.58	15.33	16.37	15.61	16.43	15.55
24(22–26)	16.83	15.68	16.66	15.85	16.71	15.81
25(23–27)	17.06	15.84	16.92	16.08	16.97	16.02
26(24–28)	17.23	16.10	17.16	16.23	17.19	16.20
27(25–29)	17.39	16.25	17.41	16.37	17.42	16.34
28(26–30)	17.70	16.45	17.58	16.54	17.64	16.52
29(27–31)	17.79	16.77	17.81	16.74	17.82	16.76
30(28–32)	17.90	17.12	17.97	16.88	17.95	16.93
31(29–33)	18.31	17.26	18.14	17.05	18.19	17.10
32(30–34)	18.52	17.50	18.20	17.31	18.30	17.35
33(31–35)	18.74	17.61	18.36	17.43	18.48	17.47
34(32–36)	18.92	17.67	18.44	17.61	18.59	17.61
35(33–37)	19.10	17.78	18.59	17.66	18.75	17.69
36(34–38)	19.14	17.82	18.86	17.86	18.93	17.85
37(35–39)	19.15	17.96	19.18	17.97	19.21	17.92
38(36–40)		17.82	19.35	18.18	19.36	18.11
39(37–41)			19.62	18.35	19.60	18.27
40(38–42)			19.67	18.56	19.67	18.45
41(39–43)			19.69	18.60	19.68	18.57
42(40–44)			19.70	18.56	19.71	18.62
43(41–45)			19.82	18.50	19.79	18.57
44(42–46)			19.68	18.51	19.71	18.65
45(43–47)			19.87	18.61	19.90	18.72
46(44–48)			19.91	18.89	19.95	18.92
47(45–49)			20.08	19.14	20.16	19.17
48(46–50)			20.24	19.43	20.25	19.49
49(47–51)			20.37	19.59	20.40	19.63
50(48–52)			20.65	19.72	20.70	19.83
51(50–52)			20.88	19.68	20.94	19.87
52			21.60	19.63	21.90	19.93

TABLE 4

Weights of Indian infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2						
3 (2–4)			7.55	6.63	7.33	6.70
4 (2–6)			8.14	7.45	7.94	7.35
5 (3–7)	8.18		8.56	7.87	8.39	7.77
6 (4–8)	8.44		9.00	8.37	8.81	8.23
7 (5–9)	8.78	7.99	9.43	8.67	9.27	8.53
8 (6–10)	9.15	8.27	9.81	8.99	9.64	8.78
9 (7–11)	9.56	8.71	10.14	9.32	10.00	9.11
10 (8–12)	9.96	9.07	10.52	9.65	10.36	9.44
11 (9–13)	10.42	9.44	10.90	9.89	10.76	9.69
12 (10–14)	10.73	9.87	11.22	10.21	11.07	10.04
13 (11–15)	11.04	10.23	11.48	10.55	11.35	10.38
14 (12–16)	11.34	10.45	11.78	10.82	11.65	10.64
15 (13–17)	11.60	10.69	12.18	11.02	12.02	10.85
16 (14–18)	11.95	11.03	12.51	11.27	12.35	11.12
17 (15–19)	12.32	11.12	12.82	11.45	12.69	11.27
18 (16–20)	12.67	11.36	13.06	11.56	12.95	11.41
19 (17–21)	13.03	11.58	13.33	11.70	13.24	11.57
20 (18–22)	13.32	11.82	13.52	11.93	13.45	11.82
21 (19–23)	13.55	11.96	13.73	12.19	13.67	12.05
22 (20–24)	13.70	12.31	13.91	12.47	13.84	12.35
23 (21–25)	13.78	12.59	14.19	12.64	14.06	12.56
24 (22–26)	13.90	12.86	14.50	12.85	14.32	12.79
25 (23–27)	14.23	13.04	14.65	12.98	14.52	12.91
26 (24–28)	14.43	13.26	14.89	13.13	14.75	13.11
27 (25–29)	14.64		15.13	13.36	14.97	13.35
28 (26–30)	14.94		15.39	13.54	15.25	13.55
29 (27–31)	15.26		15.48	13.79	15.40	13.77
30 (28–32)	15.34		15.76	14.03	15.62	14.04
31 (29–33)	15.55		15.94	14.21	15.80	14.24
32 (30–34)	15.84		16.11	14.27	15.99	14.29
33 (31–35)	16.06		16.13	14.51	16.08	14.52
34 (32–36)			16.23	14.68	16.20	14.68
35 (33–37)			16.18	14.76	16.27	14.80
36 (34–38)			16.23	14.78	16.35	14.84
37 (35–39)			16.21	15.06	16.44	15.14
38 (36–40)			16.28	15.17	16.50	15.25
39 (37–41)			16.43	15.39	16.64	15.47
40 (38–42)			16.65	15.48	16.76	15.59
41 (39–43)			16.63	15.60	16.79	15.71
42 (40–44)			16.85	15.65	16.88	15.80
43 (41–45)			17.09	15.75	17.04	15.90
44 (42–46)			17.26	15.72	17.23	15.98
45 (43–47)			17.45	16.01	17.41	16.20
46 (44–48)			17.51	16.20	17.46	16.45
47 (45–49)			17.58	16.12	17.56	16.41
48 (46–50)			17.61	16.22	17.68	16.60
49 (47–51)			17.41	16.40	17.75	16.70
50 (48–52)			17.61	16.62	17.90	17.06
51 (50–52)				17.02	18.25	17.55
52				17.66	18.71	18.54

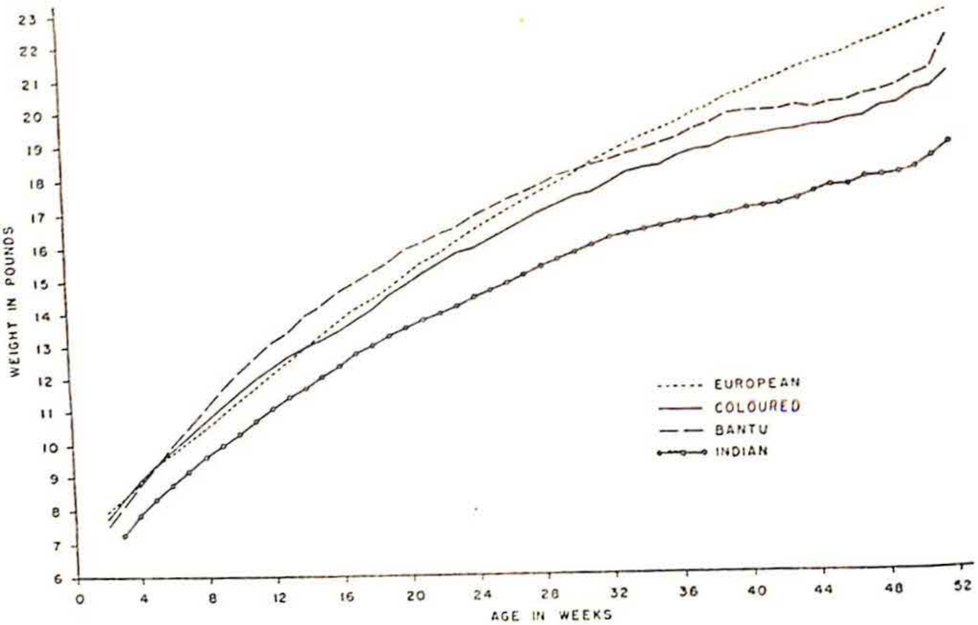

CHART 1a.
Comparison of Growth Curves of Four Racial Groups in the First Year of Life.
(boys all ranks)

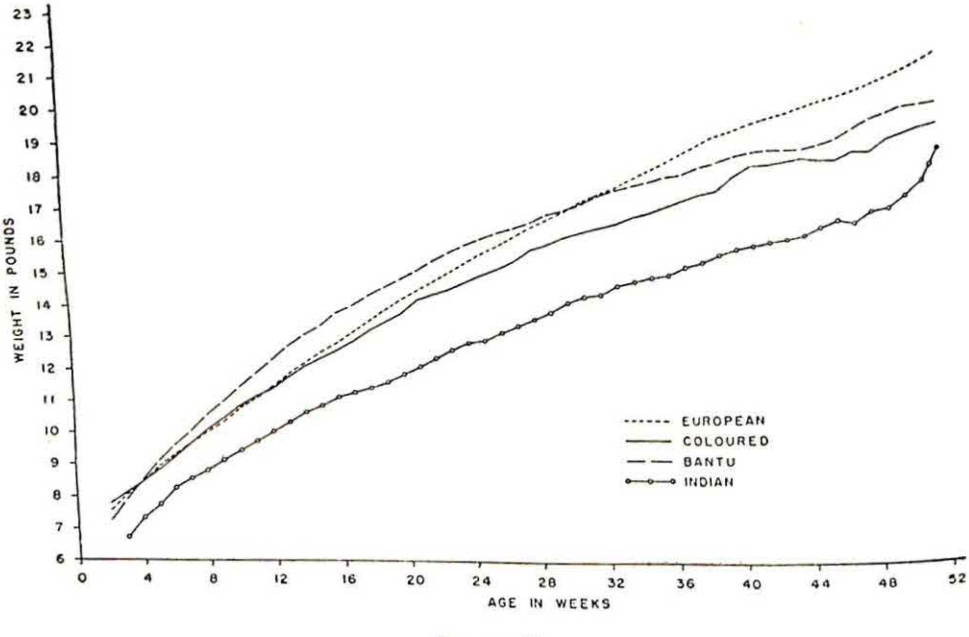

CHART 1b.
Comparison of Growth Curves of Four Racial Groups in the First Year of Life.
(girls all ranks)

Colored during the last week of the year, which may be a true picture, but is probably due to the smallness of the number at this point of the graph.

(3) The Colored boys, although they start below the European, and as we know have a lower birth weight than the European, at three weeks have reached the European level and then actually rise above the European weights, although not by very much, until 14 weeks, when once again their weights drop below the European level. Thereafter there is a gradually increasing difference between these two groups for the rest of the year.

(4) In the first 8 weeks, although the Indian boys are below the European because of their lower birth weight, the European and Indian curves run parallel to each other showing the same amount of increase. The gap widens gradually from 8–32 weeks, with considerable disparity thereafter.

(5) The Bantu pattern is quite different from the European. They start below the European because of their lower birth weight, but by 5 weeks they have overtaken the European boys and remain above their level until 30 weeks. From 30 weeks there is a marked flattening of the Bantu curve and at 51 weeks the difference between European and Bantu babies is 1.59 lbs.

Girls

(1) As with boys, at the beginning of the year European girls are the heaviest, Indians the lightest and Colored and Bantu occupy an intermediate position with the Colored slightly higher than the Bantu. At the end of the year, again, the Europeans are still the heaviest and the Indians the lightest but the Bantu are heavier than the Colored.

(2) At three weeks of age European and Colored weights are the same, 8.01 lbs and 8.02 lbs, Bantu slightly less at 7.96 lbs and Indians considerably less at 6.70 lbs. At 51 weeks the European weight has reached 21.17 lbs and the difference between European and Bantu is 1.30 lbs, between European and Colored 1.96 lbs and between European and Indian 3.62 lbs.

(3) Colored girls start off slightly heavier than European girls at two weeks of age, but from three to 12 weeks there is very little difference between them. After that the pattern is the same as that shown by the boys.

(4) The curve of the Indian girls runs parallel to that of the

European girls for the first 6 weeks only (boys 8 weeks) and after that the pattern is similar to that displayed by the boys.

(5) Bantu girls overtake European girls by four weeks and follow the same pattern as the boys, but the curve does not flatten as much and the difference at 51 weeks is 1.3 lbs (not as great a difference as the boys).

COMPARISON OF RATE OF GAIN (INCREMENTS)

Boys, all ranks (See Table 5a).

TABLE 5a

4-week increments of weight (smoothed)
boys—all ranks

	EUROPEAN		COLORED		BANTU		INDIAN	
	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week
Birth weight	7.48		—		—		—	
weeks								
0– 2	.50	4.0	—		—		—	
2– 4	.85	6.8	1.01	8.1	1.20	9.6	.85 *	6.8
4– 8	1.67	6.7	1.82	7.3	2.33	9.3	1.70	6.8
8–12	1.59	6.4	1.56	6.2	1.92	7.7	1.43	5.7
12–16	1.57	6.3	1.16	4.6	1.49	6.0	1.28	5.1
16–20	1.42	5.7	1.34	5.4	1.23	4.9	1.10	4.4
20–24	1.23	4.9	.99	4.0	.94	3.8	.87	3.5
24–28	1.14	4.6	.96	3.8	.93	3.7	.93	3.7
28–32	1.03	4.1	.94	3.8	.66	2.6	.74	3.0
32–36	.92	3.7	.67	2.7	.63	2.5	.36	1.4
36–40	.92	3.7	.52	2.1	.74	3.0	.41	1.6
40–44	.80	3.2	.38	1.5	.04	.2	.47	1.9
44–48	.74	3.0	.50	2.0	.54	2.2	.45	1.8
48–52	.81	3.2	1.20	4.8	1.65	6.6	1.03	4.1
48–50	.44	3.5	.49	3.9	.45	3.6	.22	1.7
Total 2–52	14.69		13.05		14.30		11.62	
" 2–50	14.32		12.35		13.10		10.81	

* Assuming the gain per week from 2–4 weeks to be at least as great as that from 4–8 weeks.

(1) *Europeans.* From two to 20 weeks rate of growth is most rapid varying between almost 6 ozs to almost 7 ozs per week. From 20 to 32 weeks growth is not as rapid—4 to 5 ozs per week. After that until the end of the year it is between 3 and 4 ozs per week with a total gain of 14.69 lbs from 2 to 52 weeks.

(2) *Colored.* From two to 12 weeks colored babies show their most rapid period of growth—6 to 8 ozs per week, and during the first 6 weeks

their rate of growth is even greater than that of Europeans. From 12 to 32 weeks rate of growth decreases and varies between 3 to 5 ozs per week. After that there is a fairly sharp decrease—to between 1½ and 3 ozs per week. The last four-week period shows an average increase of 4.8 ozs per week, but owing to the smallness of the numbers at this end of the scale, this is not considered a reliable figure. The total gain from two to 52 weeks is 13.05 lbs.

(3) *Bantu.* From two to 8 weeks Bantu rate of growth is the most rapid of all the racial groups being over 9 ozs per week. From 8 to 16 weeks growth is still very rapid, between 6 and 8 ozs per week. From 16 to 28 weeks rate of gain is 3½ to 5 ozs per week, and from 28 to 52 weeks it is only about 2½ ozs per week. Again the figure for the last four-week period is probably not reliable. The total gain from two to 52 weeks is 14.30 lbs.

(4) *Indians.* As there is no weight at two weeks for Indian babies owing to insufficient data, the information only starts from four weeks of age. From four to 16 weeks Indian babies grow most rapidly and gain from 5 to 7 ozs per week. From 16 to 30 weeks rate of gain has slowed and is 3 to 4½ ozs per week. Thereafter their growth is very slow—from 1½ to 2 ozs per week. Again the last four-week figure is probably unreliable. Assuming the gain per week from two or four weeks to be not less than the weekly gain from four to 8 weeks, total gain from two to 52 weeks would be 11.62 lbs approximately.

From the foregoing we see that from two to 8 weeks European boys gain the least weight of the four racial groups, with the Bantu gaining the most weight, followed by the Colored, and then by the Indian. From 8 to 12 weeks the Bantu are still gaining more than the European boys, but from 12 weeks onwards to European boys gain more than any other group. In the non-European groups the Bantu gain most weight from two to 16 weeks, more than either the Colored or the Indian. After 16 weeks, however, in spite of certain slight irregularities, Colored boys gain more than either Bantu or Indian boys. But because of the tremendous amount of weight that Bantu boys have gained in the first 16 weeks (6.94 lbs as against 5.68 lbs for European, 5.55 lbs for Colored, 5.26 lbs for Indian) by the end of the year the Bantu weights are still above the colored and Indian groups in spite of the greater birth weight and the greater gain from 16 weeks shown by the Colored boys.

In the first 14 weeks (from two to 16 weeks) Bantu boys have gained

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6.94 lbs as against only 6.16 lbs in the next 34 weeks (16 to 50 weeks). They are the only group who have actually gained more in this first period (two to 16 weeks) than during the rest of the year. This is due both to the largeness of the gain during the first period and the smallness of the gain during the second period.

Expressing the gain from 16 to 50 weeks as a percentage of the gain from two to 16 weeks, we find the following result:

European 152% Colored 122% Bantu 89% Indian 106%

Girls, all ranks (See Table 5b).

TABLE 5b

4-week increments of weight (smoothed)
girls—all ranks

	EUROPEAN		COLORED		BANTU		INDIAN	
	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week
Birth weight	7.20		—		—		—	
weeks								
0– 2	.35	2.6	—		—		—	
2– 4	.88	7.0	.67	5.4	1.17	9.4	.72 *	5.7
4– 8	1.58	6.3	1.60	6.4	2.05	8.2	1.43	5.7
8–12	1.45	5.8	1.41	5.6	1.73	6.9	1.26	5.0
12–16	1.40	5.6	1.14	4.6	1.45	5.8	1.08	4.3
16–20	1.28	5.1	1.22	4.9	1.05	4.2	.70	2.8
20–24	1.18	4.7	.90	3.6	1.07	4.3	.97	3.9
24–28	1.09	4.4	1.03	4.1	.71	2.8	.76	3.0
28–32	.97	3.9	.62	2.5	.83	3.3	.74	3.0
32–36	.95	3.8	.63	2.5	.50	2.0	.55	2.2
36–40	.91	3.6	.82	3.3	.60	2.4	.75	3.0
40–44	.66	2.6	.63	2.5	.20	.8	.39	1.6
44–48	.65	2.6	.07	.3	.84	3.4	.62	2.5
48–52	.97	3.9	.72	2.9	.44	1.8	1.94	7.8
48–50	.41	3.3	.49	3.9	.34	2.7	.46	3.7
Total 2–52	13.97		11.46		12.64		11.91	
" 2–50	13.41		11.23		12.54		10.43	

* Assuming the gain per week from 2–4 weeks to be at least as great as that from 4–8 weeks.

(1) *Europeans.* Growth rate is again most rapid from two to 20 weeks—between 5 to 7 ozs per week. From 20 to 40 weeks rate of gain is less rapid—between 3½ to 5 ozs per week. From 40 weeks onwards the gain is just over 2½ ozs per week. Total gain from two to 52 weeks is 13.97 lbs.

(2) *Colored.* Colored girls have their most rapid period of growth

between two and 12 weeks—5½ to 6½ ozs per week. From 12 to 28 weeks the gain is 3½ to 5 ozs a week and from 28 weeks onwards average gain is about 2½ ozs a week. Total gain from two to 52 weeks is 11.46 lbs.

(3) *Bantu.* Rate of gain for Bantu girls is very rapid from two to 8 weeks—8 to 9½ ozs a week. From 8 to 16 weeks gain is still rapid at 5¾ to 7 ozs a week. From 16 to 24 weeks weight gain is a little over 4 ozs a week but from 24 weeks to the end of the year the gain is rather irregular and only between one to three ounces a week. Total gain from two to 52 weeks is 12.64 lbs.

(4) *Indians.* The most rapid period of growth here is from four to 16 weeks at 4 to 6 ozs a week. From 16 to 32 weeks it has become 2¾ to 4 ozs a week. From 32 weeks onwards (disregarding the 48 to 52 week figure) the gain has slowed to 1½ to 3 ozs a week. Again a two-week weight has been assumed giving a total gain from two to 52 weeks of 11.91 lbs approximately.

Summarising the above we see that the Bantu rate of gain from two to 16 weeks is greater than that shown by the other racial groups. In the four to 8 weeks period the Colored gain is also very slightly higher than that of the European, but Indian girls always gain the least of the four groups. Bantu girls have gained the greatest amount of weight as compared with the other three groups from two to 16 weeks of age, but unlike the boys, European girls from two weeks onwards gain more weight than either Colored or Indian girls. The picture is not as clear for the girls as for the boys, but from 16 weeks Colored girls gain more than either Bantu or Indian girls.

Expressing the gain from 16 to 50 weeks as a percentage of the gain from two to 16 weeks the results are:

European 152%, Colored 119%, Bantu 96%, Indian 132%.

DISCUSSION

A fair number of growth studies in infancy mainly cross-sectional or mixed cross-sectional longitudinal have been done. A few investigators show weekly weights during the first year, others monthly weights; some given figures at four-week intervals, and yet others give results at three-month intervals. Weights are sometimes shown in kilograms, sometimes in pounds and ounces, or in pounds and fractions of pounds. It is difficult, therefore, to compare all these studies with the results of the present investigation in which the weights are shown at weekly levels in pounds and decimals of a pound. Ten American and British studies are compared with the results for white South African babies (table 6), and where results have been given in kilograms or in pounds and ounces, the figures have been converted to pounds and decimals of a pound. Where percentiles have been used, the 50th percentile, *i. e.,* the median value has been taken to compare with the means. No use was made of the results of studies given at four-week intervals, since they could not be converted to monthly figures, and where weekly figures were given the weights at 13, 26, 39 and 52 weeks were taken and expressed as 3, 6, 9 and 12 monthly weights. Figures for boys and girls are shown separately in each investigation. Most of the data are derived from child welfare clinic records, but some are selected samples of babies of good economic level receiving optimal pediatric and home care.

It can be seen that all the growth curves of the boys and girls in America and England are very similar, and the South African European figures do not differ to any extent from those of the other investigators.

The growth curves of the Colored, Bantu and Indian boys and girls however, do not folow the European pattern and deserve some detailed comment. From 2–8 weeks European boys gain the least weight of the four racial groups, but from 12 weeks onwards they gain the most, and their total gain from 2–52 weeks is 14.69 lbs as compared to 13.05 lbs for Colored, 14.30 lbs for Bantu and 11.62 lbs for Indian boys.

This picture is not as clearly seen in the girls, for European girls after two weeks of age gain more weight than either Colored or Indian girls though the Bantu girls gain more than the European for the first 16 weeks. The total gain in weight from 2–52 weeks in European girls is 13.97 lbs as compared with 11.46 lbs for Colored, 12.64 lbs for Bantu and 11.91 lbs for Indian girls.

Why do the European babies gain relatively little weight in the first 2–3 months of life when there is no doubt of their greater gain thereafter?

It is the opinion of the writer that European babies on the whole are underfed in early life when they are on the breast or given a bottle. Time and again one has seen the remark " baby overfed " when the child has gained 8 oz in a week. The mother is told to feed every four hours instead of every three or to feed for a shorter time, or to give less in the bottle. The non-European mother, on the whole ignores this advice, since in any case she usually does not have a clock and anyhow feeds " on demand." In most cases her baby is breast fed and she worries far more about whether he gets enough milk rather than too much milk.

TABLE 6

Comparison of weights in first year of life: American, British and South African (Mean weight in lbs.)

AGE	MALES										
MONTHS	1	2	3	4	5	6	7	8	9	10	11
Birth								7.5	7.6	7.63	7.48
1	8.58	9.61	9.3						8.5		
2	11.00	11.62	11.4						9.9		
3	12.76	13.31	13.4	11.89	12.16	14.34	13.05	12.6	12.1	13.06	12.49
4	14.52	14.81	15.2				14.74		13.9		
5	16.28	16.48	16.8				16.20		15.4		
6	17.60	17.86	18.0	16.10	16.77	18.67	17.46	16.7	16.8	17.5	16.88
7	18.04	19.27	19.0				18.56		18.0		
8	19.58	20.46	19.9				19.55		19.2		
9	20.46	21.45	20.7	19.35	20.34	21.70	20.47	20.0	20.2	20.75	20.13
10	20.68	22.62	21.5				21.22		20.9		
11	21.56	23.39	22.1				21.95		21.7		
12	22.00	24.11	22.8	21.46	23.13	23.82	22.59	22.2	22.4	23.13	22.67
	FEMALES										
Birth								7.4	7.3	7.38	7.20
1	8.14	8.76	8.9						8.2		
2	9.68	10.63	10.9						9.4		
3	12.54	12.12	12.7	11.24	11.25	13.02	12.16	12.4	11.2	12.06	11.83
4	12.98	13.73	14.2				13.69		12.8		
5	15.62	15.22	15.6				15.09		14.2		
6	15.84	16.24	16.8	15.13	15.44	17.04	16.36	16.0	15.6	16.25	15.85
7	16.94	17.58	17.8				17.49		16.7		
8	18.04	18.55	18.8				18.49		17.6		
9	18.92	19.29	19.7	18.12	18.70	19.73	19.34	19.2	18.6	19.13	19.07
10	19.58	20.17	20.5				19.97		19.3		
11	20.68	20.97	21.2				20.53		20.0		
12	20.46	21.56	21.8	20.09	20.56	21.88	21.03	21.5	20.8	21.50	21.52

Investigations

1. Iowa Child Welfare Research Station ('31).
2. Bayley and Davis ('35).
3. Peatman and Higgons ('28).
4. Hill and Magee ('38).
5. Lewis-Fanning and Milligan ('44).
6. Simmons ('44).
7. Gore and Palmer ('49).
8. Children's Medical Center Boston ('49).
9. Norval *et al.* ('51).
10. Parfit ('51).
11. Present Investigation (White S. African).

Even the Colored mother who is to all intents and purposes a "poor European" still tends to breast feed her baby and ignore the clock, although many Colored mothers wean their babies very early, and go to work, and non-European babies on the bottle almost invariably get too dilute a milk mixture in an attempt to make the tin of powdered milk last a little longer. It is the writer's experience, and this impression has been confirmed by many medical officers working with Indians, that Indian mothers complain of insufficient breast milk very early on. They do not wean their babies but supplement the feeds, though often inadequately. The Bantu mother, on the other hand, is a magnificent lactator, and it is the exception for her to wean the baby because of insufficient breast milk. Early weaning is far more often due to belief that her milk has been poisoned, and unless she can be persuaded to the contrary, the outlook for those babies is very bad.

Wickes ('52) quotes figures of average weight gain in the first few months of life taken from standard pediatric textbooks as 4–6 oz a week. Spock ('46) gives the most liberal figure (7–8 oz a week). In the present study figures for weight gain from 4–13 weeks are 6.5 oz per week for European boys and 6.0 oz for European girls. Wickes followed up 503 babies born at St. Bartholomew's Hospital and then singled out all infants who had temporary set-backs due to illness and feeding difficulties. This left a residual group of infants who had a "smooth passage since birth." These infants were then classified according to whether they were satisfied or not when first seen, and the 214 babies in the satisfied group were taken to be a normal collection of healthy, well-fed babies. Their rate of gain was compared with the remainder of the series. The median rate of gain of the normal infants approached 1.3 oz per day (9 oz per week). Wickes, however, considered that there was good evidence that the group still contained unrecognised underfed infants. He selected three infants whose early rate of gain exemplified the ideal to be aimed at. These babies were male, breast-fed babies who gained 16 oz per week from the second to the seventh week. Their weights at 6 months fell between 19½ and 20½ lbs and at one year they were between 25 and 26 lbs, which represented a steady gain of 3 oz per week, *i. e.*, less than one-fifth of that in the first three months. Wickes gained the impression that babies with the potentiality to gain at this optimal rate were commonly found amongst infants with feeding problems at this age. "These babies, when restricted, commonly cry and vomit. If the gain is above average, overfeeding is often suspected, if gaining normally, wind is usually diagnosed, whereas only if the gain is low is the true nature of the difficulty appreciated. Presumably many of the unsatisfied infants would have been contented if the feeds in the early weeks had been adequate to allow for some degree of 'stoking up.'"

Wickes concludes that infant feeding practice to-day underestimates the requirements of the young baby. Underfeeding he considers to be extremely prevalent due to inadequate lactation, inappropriate formulas, ignorance of the optimal rate and curve of growth, and "a morbid fear of overfeeding in the early weeks."

Wood ('52) showed that many babies admitted to hospital for vomiting of unknown origin were underfed babies. Vining ('52) found overfeeding at the breast to be exceptionally rare, but underfeeding only too common. "Babies are not like penny-in-the-slot machines, and I feel sure we have done harm in insisting on exact quantities, exact times, and feeding by the clock."

It is interesting, in this connection, to compare the mean weights of the boys and girls attending the "private clinic" of a Durban practitioner with those attending the municipal clinic. Until 14 weeks of age the private clinic children grow, if anything, less well than the municipal clinic children, showing that the same pattern of underfeeding prevailed in a better off section of the community. The effect of increased income was seen at the period of introduction of foods into the baby's diet, and was most marked towards the end of the year. (Salber '55).

TABLE 7

Gain in weight during first postnatal year of three selected infants

	M. P.		R. P.		P. P.	
WEEKS	Total gain	oz/wk.	Total gain	oz/wk.	Total gain	oz/wk.
4–13	4 lb 0½ oz	7.1	4 lb 1 oz	7.2	5 lb 2½ oz	9.2
13–26	5 " 3½ "	6.4	5 " 10½ "	7.0	6 " 5 "	7.8
26–39	5 " 3 "	6.4	4 " 10½ "	5.7	5 " 6½ "	6.7
39–50	2 " 7½ "	3.6	2 " 12½ "	4.0	3 " 2 "	4.5

As a point of interest too, the weight gains of three of the writer's children are included (table 7). Unfortunately there is no record of the weights of the first child, but his pattern was very much the same. All the children were breast-fed. M. P. (male) on an elastic four-hour schedule with night feeds, R. P. (female) and P. P. (male on "self-demand." All three showed a great potentiality for growth and all were "colicky" babies, M. P. and R. P. for 6 weeks, and P. P. for three months. Looking back at their records it seems possible that though their early rate of gain was satisfactory according to the standards taught, and although there was sufficient milk (by test feeds) it is quite likely that they required still more milk than was given them and once solids were introduced (at about 15 lbs weight) their rate of growth was very rapid indeed.

GROWTH STUDIES IN AFRICA

Trowell ('46) stated that he had never seen anything but good results in African babies from their excessive feeding. Although the African baby started at a disadvantage, liberal breast-feeding often allowed him to catch up with the European child. However, after the age of 5 or 6 months the weight of many African babies fell far below that of the Europeans and became almost stationary. This was due to the fact that the breast milk was no longer sufficient for the baby's needs, and supplementation with cow's milk and solids was inadequate for the African baby, though adequate for the European baby.

In another study Trowell ('54) stated that during the first few months of life the rate of growth was almost the same among breast-fed infants of all races, and that no difference should be accepted on the basis of race or climate until the common causes of unsatisfactory growth had been excluded. He gave three reasons for an infant's failure to thrive:

(1) Infection.

(2) Undernutrition, *i. e.*, the infant received a diet which was correct in its proportions but reduced in amount so that it did not satisfy requirements. In Uganda this occurred in the first few months of life when breast milk had failed and diluted cow's milk had been substituted.

(3) The baby is fed a diet which, though adequate to satisfy hunger, contained too low a proportion of proteins. (Trowell considered that protein should constitute 14% of the calories).

This last cause was the explanation of most cases of failure to thrive, and was the cause of all the cases of severe kwashiorkor.

Welbourn ('54) compared the growth figures of Baganda children with those of Stuart and Stevenson ('50). The birth weights of the Baganda babies fell close to the 10th percentile of the American figures. From one to three months, however, the mean weights were close to the 50th percentile of the standard figures. At about the fifth month there was a definite falling off in weight increase and from the ninth month onwards the mean weights were below the 10th percentile of the standard American figures. Welbourn says that "African babies start life as great eaters. For four or 5 months they stuff themselves with mothers' milk. But this does not prevent the inevitable hunger which follows when mothers' milk is no longer sufficient for their needs." She attributes their rapid early growth to their plentiful consumption of breast milk but during the second 6 months of life there is a marked decline in weight gain. During this time the American babies (whose weights she used for comparison) were having mixed feeding with a large variety of good foods, but the African children were having poor diets from the time their mothers' milk was insufficient for their needs.

Brock and Autret ('52) had the general impression that throughout Central Africa there is general retardation of growth similar to that recorded at Kampala by Welbourn.

Canivet ('47) compared the rate of growth of African babies in French Sudan with White French babies in France. The average birth weight of Sudanese infants was 400 gm less than that of French White infants, but at first the rate of growth of the Sudanese infants is more rapid, and their birth weight is doubled at 3½ months, whereas the French babies doubled their birth weight at 5 months. After four months the rate of growth of the black infants became less rapid and they did not treble their birth weight until the 14th month. This pattern was displayed by both male and female babies, first and later born. He explained the difference as partly physiological and partly due to the mode of life and feeding. Instead of well-regulated methods of breast-feeding, with introduction of fruit juices and mixed feeding with broth and vegetables between three and 6 months as was the French custom, the black infant was suckled by an under-nourished mother in completely irregular fashion, and the only complementary food given was adult food, which the mother had previously masticated.

Meyers ('51) studied the graph of the gain in weight of African children in Ituri, and ascertained that a decline in increase of weight was evident after 6 months.

MacKay and Martin ('52) investigated the dentition and physique of Bantu children of the Digo tribe at Msambweni in Kenya. They give the following weights for children under one year of age:

AGE	BOYS Mean (lbs)	BOYS S.D. (lbs)	GIRLS Mean (lbs)	GIRLS S.D. (lbs)
Under 3 months	10.8	3.42	9.8	2.71
3 months	14.6	1.89	12.7	2.06
6 months	16.0	1.67	14.2	2.33
9 months	16.3	1.48	15.3	1.83
12 months	19.3	2.62	18.1	2.29

It can be seen that the weights at three months compare favorably with European and American figures, at 6 months growth has slowed down but is still quite good, but in the second 6 months growth is slow and well below white standards.

Woodrow and Robertson ('50) analysed the heights and weights of colored children in Cape Town attending the municipal welfare centres The sexes were not separated. Mean birth weight was 7 lbs 5 oz and weight at one year, 19 lbs. Their graph shows the familiar pattern of retardation of growth in the second half of the year.

Matthews ('55) on a group of 374 Yoruba infants found the rate of growth to be comparable to that of British infants, during the first 6 months. From about the sixth month onwards, however, the weight increase fell below British standards, especially during the second year of life.

STUDIES OF GROWTH IN INFANCY AMONG NON-WHITE CHILDREN OTHER THAN AFRICAN

Other investigations have also shown the rapid growth in early infancy and the marked retardation of growth in the second 6 months of the year.

Gounelle and Demarchi ('53) found that up to two months the Bagdad baby had the same mean weight as the European. This initial advantage was lost at the third month and up to the seventh month there was a small but marked difference of about 400 gram (.88 lbs) between the European and the Bagdad infant at the same age. From then on the position became worse until at 12 months the difference was 1.41 kg (3.1 lbs). They found the same results too when comparing the curves for French and Iraqi babies.

During 1948-1949 the Medical Research Council of New Zealand sent a team to Western Samoa to make a survey of certain health problems (Marples '50). The main object of the investigation was to determine the incidence of skin diseases, but in a large number of children heights and weights were also recorded. The mean weights of Samoan infants up to 6 months were above, but those in the second 6 months of life were considerably below the New Zealand figures. Average weights at 12 months were in the lowest 20% of the New Zealand figures.

Su and Liang ('40) studied the normal development of Chinese infants in Hunan, by measuring infants from two well baby clinics, and compared the data with that collected by the Iowa Child Welfare Research Station. They found that the Chinese infants in Hunan, Peiping and Tsinan were not smaller in early infancy than American babies, but their growth slowed down gradually a few months later. They considered that the slow growth in the latter part of the first year could probably be explained on a nutritional basis. The babies depended too much on breast feeding and were not given supplementary feedings in most cases.

Millis ('53) investigated the gain in weight and length in the first year of life of Chinese infants born in Singapore, in order to establish their growth curves for the first year of life. She found that the curves for Chinese infants in Singapore were similar to those for Chinese infants in China. The weight increased at a similar rate to that of white infants for about 20 weeks, but the Chinese infant made slower progress in the second 6 months of the year. At one year the average Chinese male infant was 47 to 54 ounces lighter than the white infant, and the female was 54 to 60 ounces lighter. The standards for white children were taken from Vickers and Stuart ('43).

In a further study Millis ('54) investigated the growth curves in the first year of life of Southern Indian infants born in Singapore. The Indian infant was lighter at birth than the Chinese infant and tended to gain weight more slowly and like the Chinese infant showed the retardation in growth in the second 6 months of the year. The Indian infants were on an average over 4 lbs lighter than white infants at the age of one year.

Rao and Bhattacharjee ('52) analysed the growth curves of Indian infants in the first month of life. Their families belonged to the middle class economic group, and they were normal full-term infants born to healthy mothers. They stated that the range of birth weights reported by various authors seemed to be a very wide one—the lowest they quote as 5 lbs 5 oz and the highest their own figure of 6 lbs 8.5 oz which is very similar to the author's figures for South African Indian birth weights, 6.46 lbs. (Salber & Bradshaw '51). The new-born baby lost 8.6 to 10 oz in weight, (9% of birth weight) up to the third or fourth day, and thereafter steadily increased in weight, putting on 1.1 to 1.3 ounces per day until at the end of four weeks the weight reached was a little over 8 lbs. At four weeks the weight level of the South African Indian boys is 7.94 lbs and of the South African Indian girls 7.35 lbs. This study confirms the occurrence of the early rapid gain in weight previously mentioned.

NEGRO INFANT GROWTH STUDIES

Dodge ('27) analysed data of American Negro infants attending the University District Prophylactic Dispensary in Cleveland from 1914-1920. Converting his figures from grams to pounds gives the following results for weights at 3, 6, 9 and 12 months:

Boys	11.82 lbs	14.46 lbs	17.13 lbs	18.90 lbs
Girls	10.78 lbs	13.93 lbs	16.26 lbs	18.87 lbs

He states that the growth in weight of Cleveland Negro infants is definitely slower than the growth of white infants. It seems though, that the pattern of growth is not quite the same as that found in African children. Although the weights at three months are closer to the white weights than are the weights later in the year, even at three months they are well below European weights.

Bakwin and Patrick ('44) pointed out that though according to reports in the literature, the Negro infant was smaller at birth than the white infant and his growth during the first year was slower, it was not clear from the data whether these differences were due to innate or to environmental influences, since observations on Negro children had been limited to dispensary material.

Accordingly, they made a study on a group of Negro infants seen in private practice who were supervised from early life and given a good diet. They compared these babies with a group of white infants supervised from early life at the Fifth Avenue Hospital. There was no significant difference in the weight gain of white and Negro infants during the first year of life, and they concluded that " slower growth observed in earlier studies was due to differences in socioeconomic status rather than to differences in the nature of the germ plasm. Given the opportunity of proper medical supervision, Negro infants from moderate income families grow as well as white infants."

Scott *et al.* ('50) analysed the growth records of 654 Negro infants observed in private pediatric practice. These infants were from lower middle class families. Some of their conclusions are as follows:

"The mean birth weight for the male and female infants was 7.66 pounds and 7.20 pounds respectively. . . .

"At 12 months of age the weights attained were 22.59 pounds for male infants and 21.33 pounds for female infants. . . .

"We compared our results with data on Negro infants from various economic levels (general population, indigent, low middle class) reported in the literature. The infants in our study and those reported by Bakwin and Patrick surpassed those of other series in growth throughout the first year of life. A significant difference in growth was observed when indigent infants were compared with infants from middle class levels.

"We also compared our data with similar reports on the growth of white infants. There was no significant difference between the growth curves of Negro and white infants from comparable economic levels."

Meredith ('52) reviewed the literature on the size at birth and growth during the first postnatal year of North American Negro infants, and compared them with North American white babies. (See table 8). Meredith gives his figures in kilograms but the author has converted them to pounds in order to make comparison with her own figures easier.

For each Negro-white comparison within the period 1930-1950 there was approximate comparability in economic status and health care. The Negro group overall was of slightly lower economic level than the whites but all groups had reasonably adequate diets and sustained medical supervision.

In summary Meredith's findings as far as weight is concerned are:

1. Mean weight of viable Negro infants at birth is 3.23 kg (7.11 lbs), and mean weight of Negro infants weighing more than 2.2 kg at birth is 3.28 kg (7.2 lbs). The mean weights of white infants were higher by 0.12 kg (.26 lbs) and 0.13 kg (.29 lbs) respectively. The average North American Negro baby is over ¼ lb, nearly 4% lighter at birth than the average North American white baby.

2. The mean weight of Negro infants receiving adequate dietary and medical care from birth is 7.44 kg (16.37 lbs) at 6 months and 9.87 kg (21.71 lbs) at one year. Comparable means for white babies are higher by 0.20 kg (.44 lbs) and 0.13 kg (.29 lbs). At end of the first postnatal year the average well cared for North American Negro infant is not lighter than the average well cared for North American white infant by more than 2%.

From these studies of American Negroes it would appear that their growth pattern in infancy is different from that of South African Bantu and of Africans in Africa. When they are economically depressed their growth curve is generally lower than that of white infants and when they are better off economically and have good medical supervision and adequate diet their growth is the same as that of whites of comparable circumstances.

TABLE 8

Weight mean (lbs) at selected postnatal ages for North American Negro and White infants *

(Adapted from Meredith, '53)

INVESTIGATION	3 MONTHS		6 MONTHS		9 MONTHS		1 YEAR	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
1. Baldwin	90	11.15	82	14.45	73	16.50	63	18.48
	118	11.35	109	14.63	87	17.47	53	19.89
2. Woodbury	301	12.21	279	15.47	245	17.18	182	18.92
	7046	12.89	7238	16.41	7152	18.59	6476	20.24
3. Dodge; Rude	208	11.48	155	14.56	145	16.70	119	18.79
	85	12.45	96	15.27	78	17.71	101	19.12
4. Michelson	1714	11.79	981	15.91	589	18.77	338	20.92
	180	12.91	219	17.07	167	20.33	100	22.77
5. Bakwin and Patrick	102	12.50	97	16.79	99	20.11	95	22.57
Bakwin and Bakwin	218	12.58	164	16.79	115	20.02	90	22.77
6. Pasamanick;	53	14.08	53	17.93	53	20.86	53	23.21
Norval, *et al.*	2518	12.50	1943	16.76	1508	19.73	1076	21.87
7. Kelly and Reynolds	108	12.10	100	16.46	84	19.49	46	21.45
	289	12.14	269	16.59	220	19.51	124	21.63
8. Scott, *et al.*	613	12.45	600	16.90	580	20.11	553	21.91
Vickers and Stuart	254	12.56	252	17.20	241	19.93	244	22.18
9. 1930-1950 Composite	2590	12.03	1831	16.37	1405	19.54	1085	21.71
	4538	12.50	3937	16.81	3245	19.82	2640	22.00
10. Rhoads *et al.*							MALES ONLY	
							99	21.96
							134	22.13

* In each comparison the upper figures are for American Negro infants and the lower figures for American white infants.

Although the writer does not have figures of incidence of breast feeding among Negro mothers in the United States, her impression is that the incidence is far lower than amongst the non-European population in South Africa and in Africa as a whole. This impression is borne out by the study done by Bakwin and Patrick, previously cited. Of the 114 infants seen in private pediatric practice that they studied, only 40% were breast fed for the first three to four months of life, the remainder being bottle fed. Bantu babies are breast fed whenever they cry and get adequate milk in early infancy, but they suffer when mothers' milk alone is insufficient for their needs, particularly after the second 6 months of life.

To increase the mean weights of European babies one should concentrate on more liberal breast feeding (or even bottle feeding) in early life, but to increase mean weights of non-European babies, on the whole, the emphasis must be placed on earlier introduction of suitable solids in adequate amount, and the maintenance of satisfactory mixed feeding. We have demonstrated at health centres in Durban, that this can be done. At the Springfield Health Centre in 1948 Indian weights at one year had risen to 17 lbs 9 oz (17 lbs 6 oz in 1947) and Colored weights to 19 lbs 2 oz (18 lbs 11 oz in 1947). Data are not available for Bantu weights at Springfield for 1948. (These figures appear in the Training Scheme for Health Personnel Annual Report, 1948). When the Lamont Health Centre commenced its work in the Lamontville Native Location in 1948, there was a Municipal Child Welfare Clinic functioning in the area, which later closed down when the Heath Centre ran its own mother and baby sessions for the same clientele. I analysed the weight growth of the infants attending the Lamont Municipal Child Welfare Clinics in 1947 and 1948 in order to have a base line for comparison later on. The mean weights of the infants attending the Health Centre mother and baby sessions in 1950-1951 was compared with those of the municipal clinic, and we found that up to about the 30th week growth was about the same in the two peroids. After 30 weeks, however, the 1947-48 curve flattened out considerably and the average infant gained only 1½ pounds before the end of the 52nd week. The growth curve of the 1950-1951 group of infants flattened out less than the previous curve and they gained 2½ pounds in the same period, with a mean weight of 21.5 lbs at 52 weeks. (See Annual Report Lamont Health Centre 1950-51).

SUMMARY

1. Comparison of growth curves show that at the beginning of the year European babies are heaviest, Indian babies lightest, and that Colored and Bantu occupy an intermediate position with Colored babies slightly heavier than Bantu babies.

2. Colored babies weights are about the same as Europeans for about three months, and then fall progressively below them.

4. Indian babies grow as well as Europeans for about two months though their actual weights are always well below those of Europeans because of their difference in birth weight. After that they deviate increasingly from European till the end of the year.

5. Bantu babies overtake Europeans by about one month and their weights are above those of Europeans until 30 weeks of age, from which time they are below. All these remarks apply to both boys and girls.

6. Comparison of rate of gain shows that from two to 12 weeks Bantu boys gain more weight than all the other groups and from two to 8 weeks European boys gain the least of the four groups. European boys, however, gain more than the rest from 12 weeks onwards. From 16 weeks Colored boys gain more than Bantu and Indian.

7. Rate of gain of Bantu girls is greater than all the rest from 2–16 weeks, but European girls from two weeks onwards gain more weight than Colored and Indian girls. From 16 weeks Colored girls gain more than Bantu and Indian girls.

8. European babies gain far more weight than the other three groups in the second half of the first postnatal year.

9. The curve for South African European babies is similar to that of comparable babies in Europe and America. It is suggested that European infants are, on the whole, underfed in early life, due to the method of feeding on regular schedules and a fear of over feeding.

10. Non-European babies in South Africa, on the other hand, particularly the Bantu, grow well in early life, due to the high incidence of breast feeding which is given "on demand." When these babies need foods other than breast milk, growth becomes retarded because for reasons of poverty and ignorance the mothers do not supply a good and sufficient mixed diet.

11. Rapid early growth with marked slowing down in the second 6 months of life has been noted by investigators in Africa and elsewhere.

12. In America, on the other hand, where the Negro is very much a "poor white," growth of Negro babies is similar to that of white American babies, though on a lower level. When the economic groups are comparable and the infants have good medical supervision there is no difference in the pattern of growth between Negro and white American infants in the first year of life.

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THE CONSTANCY OF PHYSICAL TYPES AS DETERMINED BY FACTORIAL ANALYSIS

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IN a previous paper (Hammond, '53) the author has assessed the constancy of factorial body types among children of school ages. The present paper extends the data to cover the period from birth to 5 years. This is the period over which the maximum growth occurs and, therefore, it is the one in which there is most likelihood of the pattern of measurements changing.

The first requirement of type constancy is that the type basis should agree from one study to another. The second requirement is that within the type basis the children should remain of the same type over a period.

EFFECT OF CHOICE OF MEASUREMENTS ON THE NATURE OF THE RESULTING TYPES

Although factor analysis is completely objective in the sense that the assumptions of the factorial methods can be set out and the techniques followed by anybody with the same results, yet the resulting types depend to a great extent on the nature of the measurements initially included. This, as emphasised by Howells ('51) is perhaps a fundamental disadvantage of the factorial method of determining types, but it is inevitable in *any* form of type determination. Apart from the obvious effect of an omission of any particular group of measurements, if one physical dimension is only weakly represented by the measurements, the resulting type analysis will tend to include measurements of other groups with this weak one in order to balance a particularly strong contrasting group. For this reason it is often found that a factor may consist of a number of oddly assorted items which are merely those which fail to fall into any of the other groups.

Batteries of measurements included in different authors' investigations seldom correspond completely and, therefore, any comparison between the results must take account of this. The only rigorous way in which factors may be compared is to limit the analysis to those measurements common to the two studies; this is laborious as it involves a re-analysis from the correlation stage and it limits the amount of the data that can be included. In particular, if one is interested in the relative contributions of the general factor for physical measurements (representing isometric growth) and the type factors (representing allometric growth) in children of different ages it is necessary to include identical batteries of measurements, preferably taken upon a group with comparable age scatter. In the present studies where rigorous comparison is required, the data from different investigations have been re-analysed to produce exactly comparable sub-batteries of measurements. In other cases, however, the complete results have been used. In these latter the correspondence between results depends upon the fact that when some members of a battery of measurements are changed the factor saturations of the remaining variables alter very little. Examples are given of the change of saturation coefficients when the battery of measurements is augmented or reduced, but in some instances where the comparison is only intended to be general this relative constancy of the saturations has been assumed.

A simple measure of the over-all agreement between different results is the correlation between the factor saturations, and this measure has therefore been included.

A second major problem is what kind of factorial analysis to use. In the present case the simplest and most direct form of analysis, that of extracting a positive general factor and subsequent bipolar or contrasting general factors without any rotation, is used as the first basis for grouping the traits. Group factors are only invoked if this method proves inadequate to express the relations satisfactorily, for example when there is evidence of an odd number of groups or when the relations appear to apply to a small segment of the table of correlations only.

THE DATA

The present data consist of the author's measurements of a group of infants from the northern industrial town of Leeds (Hammond, '55b), measurements of school children (Hammond, '53b), Low's ('52) data for Aberdeen infants and Carter and Kraus' ('36) analysis of infants' measurements.

NATURE AND CONSISTENCY OF THE TYPE FACTORS

The first comparison is between the saturations derived from measurements reported on a small group of children living in Leeds who were measured annually from age one to 5 years. (Hammond, '55b). These results are also compared with those obtained from analysing the same battery of measurements taken on 200 boys and 200 girls aged 7, 9, 10 and 11 years, of similar social background from the same town and Sheffield (Hammond, '53b). The saturation coefficients for the general and bipolar factors derived from the different yearly measurement sets are shown in tables 1A and B. Table 2 gives the contribution of the general and type factors (percentage of total variance) for each year and the rank order correlations between the saturations for years 1–5 separately and 7–11 combined.

In practically all cases the type factor differentiates between the growth of long bones on the one hand, and breadth of trunk and limbs, on the other, and the corresponding types may be termed leptosomes (long narrow type) and eurysomes (broad short type). From the contributary variance figures it is evident that the type distinction is a rather minor one but apart from the saturations for the type factor for year 2 (boys) and year 5 (girls) the agreement between one year and another and between the infants and 7–11 year old children is quite close (see table 2). There was no consistent tendency for the general or type factors to increase their contribution to the total variance as the children increased in age.[1]

COMPARISON BETWEEN CONSISTENCY OF TYPE BASIS IN SCHOOL CHILDREN AND INFANTS

The constancy of the type saturations reported in the analysis of a somewhat different battery of measurements taken at ages 5–18 years (Hammond, '53a) was as follows:

Average rank order correlation = 0.83 (boys), 0.87 (girls), for the

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[1] The correlations, and, therefore, the contributory variance of the general factor will increase as the age or size range of the subjects increases but unless there is a pronounced variation in shape with age this would be unlikely to affect the type variance appreciably. In any case the age scatter of the infants (2-4 months) and children (one year) were in such proportions as to result in very similar coefficients of variation of the measurements hence a direct comparison of contributory variances can be made.

TABLE 1A

Comparison of factor results at different ages: boys (Author's data)
Saturation Coefficients

Age	1		2		3		4		5		7-11 *	
Factor	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type
Height	.697	.548	.764	.673	.902	.284	.892	.309	.816	.203	.847	.482
Sitting height	.743	.261	.731	.134	.730	.218	.906	.197	.639	.329	.819	.241
Leg length	.647	.307	.657	.180	.793	.276	.823	.259	.973	.177	.811	.356
Chest depth	.351	.093	.330	.013	.180	—.251	.286	—.400	.331	—.577	.632	—.126
Chest breadth	.450	—.140	.486	—.029	.309	.343	.450	.141	.597	.230	.693	—.194
Knee breadth	.558	—.191	.725	—.152	.845	—.400	.738	—.480	.653	—.231	.860	—.156
Ankle breadth	.583	—.045	.691	.280	.775	—.240	.783	—.131	.752	—.586	.801	.013
Interspinous breadth	.545	—.195	.641	—.214	.178	—.053	.562	.330	.477	—.030	.647	.052
Interacromial breadth	.495	—.195	.642	—.266	.638	.228	.665	—.024	.613	.518	.747	.020
Arm girth	.738	—.276	.369	—.341	.471	—.216	.477	—.251	.088	—.119	.690	—.460

* Note: means, variances and co-variances were calculated within years.

TABLE 1B

Comparison of factor results at different ages: girls (Author's data)
Saturation Coefficients

Age Factor	1 Gen.	 Type	2 Gen.	 Type	3 Gen.	 Type	4 Gen.	 Type	5 Gen.	 Type	7-11 * Gen.	 Type
Height	.733	.230	.856	.364	.914	.183	.745	.506	.858	.492	.835	.519
Sitting height	.697	.165	.817	.238	.838	.314	.870	.203	.682	.450	.802	.278
Leg length	.615	.247	.582	.553	.825	.193	.710	.356	.742	.190	.828	.269
Chest depth	.411	.032	.506	—.151	.367	—.630	.159	—.339	.529	.019	.654	—.150
Chest breadth	.519	—.245	.617	.037	.581	—.316	.463	—.070	.535	—.118	.691	—.099
Knee breadth	.619	.070	.808	—.299	.783	.027	.803	—.102	.823	—.283	.838	—.229
Ankle breadth	.427	.234	.748	—.096	.750	.293	.660	.059	.778	—.433	.666	—.168
Interspinous breadth	.552	—.250	.602	—.114	.565	.125	.709	—.136	.477	—.144	.620	—.072
Interacromial breadth	.596	—.364	.847	—.002	.606	—.023	.637	.044	.699	—.080	.677	.239
Arm girth	.692	—.250	.650	—.469	.665	—.254	.615	—.517	.613	—.005	.665	—.595

* Note: means, variances and co-variances were calculated within years.

general factor; 0.94 and 0.97 for the first type factor; and 0.74 and 0.77 for the second type factor. Again, there was no clear tendency for the type differentiation either to increase or decrease with age.

We now have a situation where two different batteries of measurements, those of the pre-school children and school children, respectively, give fairly consistent groupings of the measurements but because of the choice of measurements, the resulting types necessarily differ. Children in the pre-school group were divisible into length-breadth (leptosome-eurysome types) and in the school children's groups the major differentiation was between length and girth (leptosome-pyknic types) with the breadth (being weakly represented) thrown into the length group. However, for the school children's groups, lengths, breadths and girths were all shown to be distinct when the breadth and length or breath and girth measurements were analysed separately.

TABLE 2

Contributary variances and rank order correlations between saturation coefficients obtained for years 1-5 and 7-11 compared with the average rank

	GENERAL FACTOR				TYPE FACTOR			
	Contributary variance		ρ		Contributary variance		ρ	
	boys	girls	boys	girls	boys	girls	boys	girls
Year 1	35.2%	35.4%	.75	.78	6.9%	5.2%	.81	.65
Year 2	39.9%	49.7%	.95	.75	8.1%	7.7%	.61	.94
Year 3	40.8%	49.7%	.90	.95	7.0%	8.1%	.81	.72
Year 4	47.2%	43.5%	.96	.82	7.9%	8.4%	.78	.98
Year 5	41.6%	47.0%	.82	.88	12.4%	7.9%	.70	.47
Years 7-11	57.6%	53.6%	.91	.89	7.1%	9.5%	.81	.91

For example, when 21 breadths and girths were analysed by a bi-polar analysis they formed two distinct groups, the only exception being knee breadth which formed part of the girth group (but as its saturation for the type factor was less than 0.1 it was not significant). Similarly, when lengths and breaths alone were analysed the type factor differentiated between these groups without exception. A bi-polar analysis applied to a battery containing length, breadth and girth measurements must necessarily result in a mixed grouping for the type factor. We would, therefore, expect three type components, length, breadths and girths to show up if a group factor analysis were applied to the appropriate measurements.

At ages 3, 4 and 5 years measurements of chest girth, weight and sub-cutaneous fat were added to the battery and a group factor analysis was applied.[2]

TABLE 3

General and group factor analysis of 13 measurements (boys)
Factor saturations

	AGE 3				AGE 4				AGE 5			
	General factor	Group factors			General factor	Group factors			General factor	Group factors		
		1	2	3		1	2	3		1	2	3
Height	.60	.60			.82	.48			.79	.38		
Sitting height	.64	.38			.82	.42			.54	.46		
Leg length	.53	.55			.75	.43			.85	.41		
Chest breadth	.19	.37			.42	.22			.55	.28		
Acromial breadth	.33	.58			.63			.26	.43	.48		
Chest depth	.16		.37		.37		.40		.29		.43	
Spinous breadth	.29		.06		.52	.41			.41		.12	
Knee breadth	.84		.01		.77		.16		.84		.04	
Ankle breadth	.69		.14		.85		.48		.65		.39	
Arm girth	.53			.19	.41			.58	.10			.50
Chest girth	.75			.16	.74			.00	.06			.37
Subcutaneous fat	—.06			.55	.34			.48	—.09			.50
Weight	.90			.10	.90			.17	.91			.60

As shown in table 3 the three type factors represent respectively (1) long bone measurements (with shoulder breadth), (2) trunk and limb breadths (with chest depth) and (3) measurements affected by the soft tissues, namely, arm and chest girths, weight and sub-cutaneous fat.[3] Clearly a larger battery of measurements is required to define these factors more adequately. At age 5, 22 measurements and at 7–11 years, 29 measurements were taken consisting of measurements of long bones, girths and breadths of limbs and trunk together with weight and sub-cutaneous fat. The results of applying a similar group factor analysis to the correlations are shown in table 4.

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[2] The method of analysis used was to sort the variables initially according to the first three factors of the bi-polar analysis, then calculate new basic factor saturations by the ordinary summation method of Burt's ('40, p. 459) general factor procedure, but using approximations for the whole trace consisting of those correlations which are augmented by the group factors instead of for the diagonal element alone. The sums of the elements of the trace were calculated as the products of the provisional basic saturation coefficient for each variable times the sum of the saturations of the other variables contributing to the group. The result is to produce a battery in which the general factor is not influenced by the group factors and from which they rise as positive clusters above the basic general factor level.

TABLE 4

Comparison of group factor saturations

	BOYS							GIRLS						
	5 year group Group factor			7-11 year group * Group factor				5 year group Group factor			7-11 year group * Group factor			
FACTOR	1	2	3	1	2A	2B	3	1	2	3	1	2A	2B	3
Height	.730			.653				.730			.760			
Sitting height	.414			.545				.512			.595			
Leg length	.540			.585				.533			.728			
Arm length	.456			.635				.427			.654			
Foot length	.412			.588				.574			.599			
Hand length	( )			.585				( )			.517			
Interacrom. br.	.349			.325		.236		.429			.517		.091	
Foot breadth		.125		.343	.306				.051		.348	.501		
Hand breadth		.450		.346	.406						.496	.488		
Ankle breadth		.548			.308				.219			.500		
Knee breadth		.026			.285				.319			.487		
Wrist breadth		.469			.487				.173			.513		
Elbow breadth		( )			.361							.458		
Chest depth		.029				.030				.426				
Chest breadth			.263			.139				.506			.190	
Interiliac br.			( )			.330							.369	
Inter-spin. br.	.114					.368							.433	
Inter-troch. br.			.234			.236		.263					.216	
Wrist girth					.419							.511		
Ankle girth					.276							.579		
Arm girth			.557				.620		.671	.265		.495		.682
Knee girth			.415		.193		.508		.250	.475				.547
Calf girth			( )				.487			( )		.519		.506
Chest girth			.366				.418			.284				.444
Waist girth			.662				.502			.485				.543
Hip girth			.564				.522			.490				.543
Fat			.710				.713			.520				.764
Weight			.384				.426			.424				.453

* Note: means, variances and co-variances were calculated within years.

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[3] The effect on the general factor saturations of adding variables is only slight, the rank order correlations (ρ) between the original saturations and new general factor saturations were .89, .99, .98 (boys) at ages 3, 4 and 5 years, respectively,

The group factors which result from the two batteries of measurements for boys and girls agree fairly well; there is no major discrepancy in the grouping of the variables which are common to both studies. Again three group factors result, corresponding to a factor for length measurements, another for bone breadths, and a third for girths with weight and fat. In the school children's group the breadth measurements could be subdivided into limb breadths together with ankle and wrist girths—which were minimum measurements largely concerned with bone formation (designated factor 2a) as distinct from trunk breadths (designated factor 2b). In boys, calf girth appeared in the girth group and also in the limb breadth group but only in the girth group for girls. Foot and hand breadth also showed some overlap appearing in the long bone group and in the limb breadth group (factor 2a).[4]

These results show fairly clearly that when a sufficiently wide selection of body measurements is taken they can be differentiated into long bone measurements (including shoulder breadth) as the major group, girth measurements involving muscle and fat, as the next important group and breadth of limb bones and trunk as a less homogeneous third grouping. These are apart from any head or face measurements which also show their own groupings.

COMPARISON WITH OTHER STUDIES

The foregoing comparisons have been made between the author's own studies where many or all the measurements have been the same. Since the saturations of the common variables have remained much the same when measurements have been added, it is legitimate to compare the order of saturations of the variables common to these and the results of other investigators without requiring that all the measurements should be the same and without having to reanalyse the common parts of the tables. This has been done in comparing the present results with those of Carter and Kraus' analysis of the Bakwins' data and the author's analysis of correlations between body measurements derived from Low's

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compared with correlations of .77, .86, .81 for ages 3 with 4 and 5 years, and 4 with 5 years, respectively, for the same children and the same battery of measurements. This is evidence in favor of the general factor being very little different in the two cases and therefore representing true all round growth, rather than merely the common elements of a limited number of measurements.

[4] Hammond ('42) also gave hand breadth in the long bone factor.

Aberdeen study even though Carter and Kraus' study included many head measurements. The results are set out in table 5.

The major body measurement can be differentiated into length and breadth or girth measurements with very minor exceptions.

TABLE 5

Factor saturations: comparison with other results

	BOYS			GIRLS		
	Carter & Kraus	Low	Hammond	Carter & Kraus	Low	Hammond
Total length	.54	.32	.46	.52	.36	.30
Sitting height	.58	.23	.30	.51	.11	.20
Leg length	.34	.27	.32	.34	.51	.28
Foot length	—	.30	—	—	.19	—
Cubit length	—	.36	—	—	.28	—
Palm length	.14	—	—	.15	—	—
Middle finger length	—.26	—	—	—.28	—	—
Head length	—	—.15	—	—	—.11	—
Shoulder breadth	—.06	—.31	—.24	00	—.35	—.29
Hip breadth	—.30	—.23	—.18	—.42	—.14	—.24
Chest breadth	—	—	—.18	—	—	—.27
Chest depth	—	—	.07	—	—	.01
Chest girth	—.09	—.23	—	—.06	—.18	—
Upper arm girth	—	—	—.40	—	—	—.27
Palm breadth	—.11	—	—	—.02	—	—
Head breadth	—	—.50	—	—	—.28	—
Knee breadth	—	—	—.19	—	—	.06
Ankle breadth	—	—	—.06	—	—	.18
Weight	.40	—.20	—	.36	—.28	—

To summarise the findings: the factors distinguish between length measurements, which are probably affected by the state of closure of the epiphyses, and the girth measurements which are affected by the amount of overlying fat and muscle tissue.[5] Besides this major distinction there

[5] Analyses of measurements of subcutaneous fat taken at different sites of the body always show such high correlations with each other and low correlations with other body measurements as to indicate a very strong group factor (Brožek and Keyes, '51; Hammond, '55a). The presence of a similar factor for muscle development alone has not been shown in the tables reported here since the techniques used were not capable of differentiating adequately between muscle and fat. (Measurements of breadths across the chief muscles with blunt-pointed

are two sub-groups corresponding to limb breadth development or trunk breadth development and these are related to some extent. Which of these groupings appears first, that is, whether all trunk or all limb measurements go together or whether the breadths go together irrespective of whether they are on trunk or limbs depends largely upon the combination of measurements included in the whole battery. However, in all the batteries of measurements studied the groupings have been limited to the above combinations. These results are all obtained with unselected populations—if persons were to be selected according to their physical characteristics, almost any combinations of measurements could be produced.

THE INDIVIDUAL'S TYPE CONSISTENCY

So far we have only considered the consistency of the type basis. We can say that similar types appear consistently in all ages of children studied; there are leptosomes at birth, during the pre-school years and throughout the school years, but it does not follow from this that the individuals who are leptosome at birth or in infancy will necessarily be so at the later ages. To check this we must assess the constancy of the individual type measurements. This can be done in terms of weighted type factor measurements based on regression equations, simple sums of diagnostic measurements or ratios of measurements indicative of body type. In the study of school children, regression equations were used to calculate the individual's type measurement and the resulting factor measurements gave continuous distributions. On being repeated after an interval of three years the factor measurements gave correlations ranging from 0.65 to 0.92 for the different sex, age and social groups. The percentages changing type (on a twofold classification) averaged 11% up to 13 years and 18% from 14 onwards in boys, compared with 8% up to 9 years, 12% over 14 and 22% during the ages 10–13 for girls. In these cases the growth between the intervals of measurement was slight compared with the degree of existing type differentiation. In the case of infants, growth from birth to 5 years is relatively much greater so that we should expect more type changes to occur.

At one year of age the babies were typed using an unweighted sum

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calipers using sufficient pressure to eliminate the fat contribution, or measurements of X-rays at different parts of the body would be needed to show a group factor for muscle development as a sub-group of the girth component.) A rating for muscularity can also be made by adjusting for the fat covering contributing to girth measurements.

of length and diagnostic breadth measurements which had equal standard deviations (in order to remove any bias if one type grew more than the other) and from the continuous distribution of factor measurements the middle 50% were selected (equivalent to taking the mean ± 1 p. e.)

TABLE 6

Mean measurements for three physical types selected at age one year with sample re-measured at age 5 years

	Leptosomes		Mesosomes		Eurysomes	
BOYS	1 yr	5 yr	1 yr	5 yr	1 yr	5 yr
Number	70	7	84	14	60	15
Weight (lbs)	21.5	41.2	23.3	39.7	22.9	39.9
Height (cm)	75.2	110.1	72.9	108.5	71.5	107.4
Sitting height	46.7	62.7	45.3	61.6	43.9	60.6
Leg length	30.6	50.5	29.3	49.4	28.3	51.9
Bi-iliac breadth	11.4	15.6	11.6	15.5	11.6	15.5
Bi-acromial breadth	17.0	23.5	17.2	24.0	17.6	23.6
Chest breadth	13.7	17.0	13.7	17.4	13.9	17.4
Chest depth	12.6	13.6	12.2	13.5	12.3	13.8
Arm girth	15.8	16.5	15.7	16.7	16.0	16.6
Knee breadth	5.58	7.68	5.45	7.60	5.50	7.54
Ankle breadth	3.58	5.24	3.58	5.15	3.46	5.12
GIRLS						
Type 'score'	57.1	52.1	53.0	46.8	48.9	48.3
Number	58	5	116	15	63	19
Weight (lb)	21.6	42.5	21.8	40.7	21.8	40.4
Height (cm)	73.9	111.4	72.0	109.1	70.2	107.7
Sitting height	45.9	62.5	44.6	60.9	43.5	60.6
Leg length	30.5	50.9	29.3	50.4	28.2	49.9
Bi-iliac breadth	11.4	15.3	11.3	15.7	11.5	15.2
Bi-acromial breadth	16.5	24.1	17.0	24.0	17.2	23.5
Chest breadth	13.4	17.5	13.5	16.9	13.7	17.1
Chest depth	12.2	13.6	12.0	13.4	12.1	13.5
Arm girth	15.1	17.0	15.5	16.8	15.7	17.2
Knee breadth	5.39	7.60	5.34	7.34	5.36	7.44
Ankle breadth	3.43	5.27	3.33	5.15	3.34	5.15
Type 'score'	57.0	51.2	52.6	48.5	48.7	47.0

as the mesosomes and the outer 25% forming the length group as leptosomes and the broadest 25% as the eurysomes. The mean measurements of these three types at ages one year and 5 years are shown in table 6. The measurements show the average type characteristic and at age 5 the original groups ase still distinct, although the eurysomes and mesosomes now show little difference in their mean type 'scores' as shown by the figures at the foot of the columns in table 6. If, now, individuals are re-allocated to types on the basis of the fifth year measurements and their correlations, three type groups can again be recognised. These show much the same differentiation as the first year types but are composed of slightly different groupings of individuals. As we might expect, the type pattern for these groups is more distinct than for the children typed 4 years before, showing that the intervening growth has tended to mask the type distinction. The new type measurements are shown in table 7.

TABLE 7

Mean measurements for three body types re-selected at age 5 years

	Leptosomes		Mesosomes		Eurysomes	
	Boys 7	Girls 10	Boys 14	Girls 17	Boys 9	Girls 10
Weight	40.5	41.1	40.4	39.6	38.6	43.2
Height	110.6	114.9	109.5	108.1	105.3	107.7
Sitting height	63.5	62.4	61.4	60.3	59.8	60.5
Leg length	49.9	52.1	49.7	50.1	47.9	49.7
Biacromial breadth	23.36	23.78	23.93	23.67	23.83	23.85
Bitrochanteric breadth	19.21	19.13	19.36	19.28	19.22	19.45
Chest breadth	16.93	16.72	17.75	17.17	17.33	17.20
Knee breadth	7.61	7.30	7.58	7.31	7.58	7.72
Ankle breadth	5.26	5.04	5.15	5.14	5.08	5.30
Chest depth	13.42	13.22	13.82	13.58	13.50	13.40
Arm girth	16.30	16.66	16.66	16.54	16.86	18.34
Chest girth	55.0	53.8	55.6	53.9	54.4	56.1
Body fat	33.0	34.0	32.6	35.9	34.0	47.6
Type 'score'	46.7	52.1	39.7	40.3	33.2	34.2

The actual numbers of type changes from age one year to age 5 compared with the numbers expected (in brackets) were as follows: 42% (50%) one type change; from mesosome to eurysome or leptosome, or the converse, 6% (14%) two changes; from eurysome to leptosome, or the converse. All the extreme changes were from eurysome to leptosome at the second typing. The χ^2 value, 13.1, shows that as few changes as this would be expected to appear only about one in a 100 times had there been no association between the types. That is, there was a significant type consistency over the period although it was not high. The correlations between type scores at one year and 5 years were .51 and .30 for boys and girls, respectively. Similar results for children who were typed at age two in comparison with their type at age one showed that 41% of the boys and 58% of the girls changed their type from mesosome to eurysome or the converse (compared with an expectation of 49%) but only 2% changed from eurysome to leptosome or the converse (compared with an expectation of 17%). Thus 57% of the boys and 40% of the girls remained classified the same on both occasions compared with an expectation of 34%. The correlations between the type values at first and second year measuring were 0.71 for boys, and 0.52 for girls.

In sample groups of 64 school boys aged 8 years and 78 girls aged 7 years, the correlations between the first and second unweighted type measurements after an interval of three years were 0.86 and 0.69 respectively. If the growth in length and girth were unrelated to the type, the expected correlations would be 0.60 and 0.72. The boys, but not the girls, have therefore shown greater type consistency than would be expected from the contribution which the first measurements make towards the later measurements. In th girls' group a few individuals made extreme changes, some through being unusually fat at the first measuring and later showing more average proportions, and others through increasing in fat and therefore in girths. There were 4 changes of type (on a two-fold classification) among the boys (all being borderline cases at both measurings), but 8 girls changed their type, two of them markedly.

In the same way type ratios may be studied from one year to the next and table 8 shows the correlations between

$$\frac{\text{weight}}{\text{height}} \quad \frac{\text{height}}{4 \text{ x biacromial breadth}} \quad \text{and} \quad \frac{\text{chest girth}}{\text{height}}$$

(all of which can be used as type indicators) for the Leeds children or Low's Aberdeen children from birth to 5 years.

TABLE 8

Correlations between type ratios for successive years from birth to five years and 10-13 years

		N	birth–1	1–2	2–3	3–4	4–5	N	10–13
Ht./biacrom	Boys	66	.04	.49	.37	.59	.78		
(Low)	Girls	60	.08	.42	.32	.76	.73		
Chest/Ht.	Boys	66	.43	.51	.56			200	.82
(Low)	Girls	60	.15	.59	.76			200	.70
Wt./Ht.	Boys	66	.40	.57	.70	.66	.81		
(Low)	Girls	60	.09	.32	.67	.80	.86		
Wt./Ht.	Boys	214	.10	.50				200	.88
(Hammond)	Girls	237	.16	.50				200	.97

Correlations between measurement types and type ratios were as follows:

	Boys	Girls	
Ht./4 x Biacrom.	.55	.80	
Chest/Ht.	.86	.89	
Wt./Ht.	.38	.48	(with length breadth type distinction)
Wt./Ht.	.64	.59	(with length girth type distinction)

The correlations between the weighted combination of height and biacromial breadth at birth compared with later ages to 5 years (not shown) were around zero and similarly for the other ratios, showing that the physical characteristics at birth bear only slight relation to the later body form. The above figures show that the correlations between successive years' measurements increase with age.

TYPE CONSISTENCY IN TERMS OF GROWTH PATTERN

The above type consistency is partly a necessary consequence of the fact that growth between successive intervals of measuring may be so slight (relative to the variation in attained measurements) as to be incapable of upsetting the type position once established, whatever the nature of the growth. A more fundamental type consistency would be that in which the individual having become differentiated into a type at birth, say, will then proceed to grow in a way which maintains or accentuates this configuration. We need, therefore, to see whether growth itself shows type characteristics and to study the growth which occurs in different physical types.

In the first place, if there is type or directional growth it should be apparent in the same way that measurement types could be recognized from the analysis of correlations; in this case, the correlations would not be between attained measurements but between growth increments. The growth increments calculated from Low's children from birth to 5 years and the Leeds children from one to three years have been correlated and the results of factorising the correlations are shown in table 9.[6]

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[6] After age 5 the differences in birth measurements are so small relative to the attained measurements that the correlation between increments from birth will be virtually the same as the correlations between the attained measurements and, therefore, types of growth will be much the same as the measurement types.

The grouping of growth (*i. e.*, type growth) which becomes evident after the general growth influence has been partialled out follows a distinction into length and non-length growth similar to the classification of attained measurements. The general growth influence is again stronger than the differentiating growth influence; the general growth factor contributions to the total variance being 29.5% boys, 43.5% girls (Aberdeen) and 18.1% (Leeds children) compared with the type factor variance of 6.4%, 7.2% and 7.9%.

TABLE 9

Factor saturations for children's growth

	GENERAL FACTOR SATURATIONS			TYPE SATURATIONS		
	Aberdeen (Low)[1]		Leeds (Hammond)[2]	Aberdeen (Low)[1]		Leeds (Hammond)[2]
	Boys	Girls	Boys & Girls	Boys	Girls	Boys & Girls
Stature	.840	.723	.710	.306	.455	.407
Sitting height	.825	.802	.479	.080	.286	.375
Leg length			.265			.150
Cubit	.510	.722		.250	.327	
Foot length	.577	.553		.118	.076	
Head length	.293	.601		.050	.134	
Head breadth	.320	.485		—.129	—.061	
Inter-acromial br.	.108	.369	.402	.250	—.395	—.235
Inter-trochanteric br.	.330	.585	.009	—.392	—.365	—.113
Chest depth			.092			—.236
Chest breadth			.550			—.504
Ankle breadth			.452			.021
Knee breadth			.488			.107
Chest girth	.400	.619		—.395	—.270	
Arm girth			.299			—.238
Weight	.730	.899		.194	—.149	

[1] Birth to 5 years.

[2] One to three years.

The variance of the type or directional growth ranges from 1/6 to 2/5 of the variance of all-round growth, depending upon the interval. Therefore, even if the type growth were perfectly correlated with the attained measurements at a fixed age we would still find that children would tend to grow in all directions irrespective of their type. Only when these general growth differences were allowed for, would the relatively greater length or breadth growth have its effect.

Having shown that type growth does occur but that it is much less evident than general all-round growth, we need next to see whether it is related to the existing body type; *i. e.,* do leptosomes continue to show relatively more length growth, pyknics growth in girth and eurysomes growth in breadth?

The three type groups in the original Leeds sample of 451 children classified at one year of age on the basis of length and breadth development into leptosomes, mesosomes and eurysomes, showed the same weight increase (this being a good indicator of all-round growth) from birth to one year (Hammond, '52). This is confirmed by Low's data where correlations of weight increase with type measurements are also all about zero. The mean weight increase and growth in all the other dimensions for a sample followed up from one year to 5 years for the leptosome, mesosome and eurysome types, are shown in table 10.[7]

TABLE 10

Mean growth from one year to 5 years according to physical type

		Leptosomes		Mesosomes		Eurysomes	
	n.	7	5	14	15	15	19
		Boys	Girls	Boys	Girls	Boys	Girls
Weight	lbs	19.7	20.9	16.4	18.9	17.0	18.6
Height	cm	35.1	38.0	35.6	37.1	36.3	37.1
Sitting height	"	15.2	16.4	16.3	15.9	16.5	16.9
Leg length	"	20.0	20.7	20.1	20.4	23.2	21.3
Interacromial breadth	"	5.94	7.63	6.31	6.71	5.41	5.91
Interspinous breadth	"	3.83	4.20	3.67	4.15	3.90	3.56
Chest breadth	"	3.30	4.32	3.68	3.62	3.54	3.53
Chest depth	"	0.90	1.68	1.50	1.50	1.54	1.30
Knee breadth	"	2.23	2.37	2.21	2.04	2.08	2.09
Ankle breadth	"	1.82	1.99	1.69	1.89	1.52	1.74
Arm girth	"	0.58	1.60	1.12	1.60	0.54	1.42

The growth shown by the three types is similar in pattern but the leptosome girls gained more in all measurements. The other types actually gained *relatively* somewhat more in length than the leptosomes who tended to 'fill out' and broaden. This accounts for the fact that the original types show a diluted form of differentiation at age 5 compared with groups selected afresh, and that hardly any distinction remains between the measurements of the original mesosome and eurysome types.

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[7] Although the figures at age 5 are based on less than a fifth of the group measured at age one, the results can be accepted with greater confidence than their small numbers would suggest because this sub-sample had practically identical measurements with those of the original group (table 6) and they also agree very closely with the means for a larger group of children from other northern towns studied on another occasion (Hammond, 1953b).

The total increase in weight shown by the leptosome and pyknic types in the school children's sample referred to previously did not differ. The types also gave the following totals of length and girth growth (equivalent to type growth) over an interval of three years.

	SUM OF LENGTH GROWTH cm		SUM OF GIRTH GROWTH cm	
	Boys	Girls	Boys	Girls
Leptosome	36.4 ± 1.1	36.3 ± 1.0	25.1 ± 1.3	28.5 ± 1.8
Pyknics	37.4 ± 1.2	36.4 ± 1.0	23.2 ± 1.6	22.2 ± 1.4

Only the girls' increase in girths was significantly different for the two types: the pyknics increased their girth *less* on average than did the leptosomes. This accounts for the correlations between first and second typing being less than expected if growth were random with respect of initial type in the case of girls.

In young children there is little consistency in type but if one examines other aspects of development the same unpredictability is found; for example, correlations between attained weights or heights at birth and at periods up to 5 years are only what would be expected from random growth superimposed upon the attained measurements at any moment.

TABLE 11

Correlation between attained weight and height with birth weight and length

	Birth to 1 year			2 years			3 years			4 years			5 years		
	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*
WEIGHT															
Boys	214	.49	.42	44	.33	.43	24	.44	.40	34	.39	.31	30	.38	.38
Girls	237	.22	.42	45	.67	.38	35	.07	.27	40	.16	.22	37	.17	.22
HEIGHT															
Boys		.55	.60		.22	.48		.27	.37		.29	.37		.35	.34
Girls		.26	.54		.39	.45		.24	.40		.30	.36		.30	.33

* Expected correlation is based on the assumption that

$$r = \sqrt{\frac{\text{birth weight variance}}{\text{birth weight variance} + \text{variance of growth}}}$$

Although the correlations are significant they are not higher than would be given by assuming the intervening growth to be independent of the birth measurements. Moreover in the case of lengths, the variances of the separate yearly growth may be added to give the variance of the growth from birth to any age (showing that there is negligible correlation between the successive annual gains). Another aspect of growth affecting type consistency is that the growth in different dimensions shows spurts or troughs in the same individual and the correlations found between weight gain from birth to two years and from 3-5 years were around zero.[8] For height gain, which in girls showed the greatest consistency, the correlation only equalled 0.26 and was zero for boys. Type growth (difference between length and breadth increases) only gave correlations of 0.15 for girls and 0.08 for boys over the two periods.

There is fairly considerable evidence (Weir '52, Hammond '53b) that the higher social classes are more leptosome than the lower ones. In addition they show greater relative length growth than weight growth so that the socially determined types increase their type differentiation as they increase in age. This is shown clearly by the means of different children at different ages and also by following up the actual growth.

The author's work on groups of children of different nutritional state has also shown that the groups with poor nutrition contain a bigger proportion of leptosomes but that, in addition, their growth tends to accentuate this pattern. On groups of more homogeneous social background reported here, on the contrary, there appears to be little relation between the type and the ensuing growth.

DISCUSSION

The most difficult part of the interpretation of physical types emerging from the present analyses is to account for the level of consistency (or its absence) in children of different ages. It is fairly clear that the same kinds of types can be distinguished at all ages from infancy to adulthood, and that when growth is analysed it also falls into similar patterns. However, whilst growth can accentuate or decrease the type distinction, a child's measurements at the later ages will necessarily bear some relation to what they were earlier, even as far back as birth, on account of the contribution of the first attained measurements to the later ones.

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[8] The intervals were chosen to avoid consecutive periods, as any measuring errors would tend to give negative correlations.

The period from birth to 5 years covers the maximum growth and indeed includes about half of the total growth that occurs in length and 2/5 of the total weight gain from birth to adulthood, so that to test for type consistency between birth and 5 years is equivalent to testing that from 5 years to maturity (the coefficients of variation being comparable at the two ages). This is therefore a rather strict test. In later childhood, by contrast, just because growth is so slight relative to attained measurements, the type consistency must be relatively high. Even at adolescence the change in growth pattern is still relatively slight as well as being temporary (due to the different times of onset of measurement spurts) and so type consistency will still be fairly high over this period. The correlations found between the type values over an interval of three years for school children (even including the adolescent period) average over 0.8. In part, the high type consistency is due to this contribution of the earlier measurements to the later body form but also the analysis of the growth shows that it consists mainly of a general increase in all directions and this does not alter the type. Part of the growth is differentiated into directions corresponding to relatively greater or lesser increase of lengths, girths or breadths in much the same way that the attained measurements were grouped.

This correponds to true type growth, yet in the groups studied it has been very difficult to demonstrate any correlation between the kind of growth which occurs and the different attained body types. In those type groups which were also distinguished by social class, the leptosomes tended to become more clearly differentiated from the pyknics and this was also true to a lesser degree of a group in which the types were associated with nutritional state, but the types as such have on the whole failed to show specific growth characteristics. This may partly be due to the fact that growth itself is not consistent from one period to another as shown by the present study, the author's unpublished growth analyses of other groups, and also previously by (Muhsam '47). In general it looks as though the growth is randomly superimposed on the body types found at any moment. The result is that most individuals, whatever their type may be, tend to increase in general size by greater or less amounts during any interval. However, in addition some few will accentuate their type becoming relatively longer, more rotund or broader, others tend to compensate and so decrease their type shape but most continue to maintain their proportions. A balance between these opposing tendencies is necessary if an amorphous inter-type is not to result. The rather slender evidence afforded by the contributory variance of the type and general factors at different ages suggests that there is no clear tendency for types to become more strongly differentiated at any one part of the growing period than another. The constancy of the types will naturally be highest at those times where the growth is least, *i. e.,* from about 5 years to 10 or 11 years. Temporary changes of type may occur at adolescence due to the time lag between the growth spurts of different parts of the body. In adults entirely different conditions apply because the all-round growth which characterises childhood no longer occurs. In adults weight and the girths may change considerably mainly through the accumulation or loss of fat, but lengths do not alter comparably and, therefore, whatever weight change occurs is more likely to alter the type form.

SUMMARY

Factor analyses of body measurements for infants from birth to 5 years have shown that length, girth and breadth types similar to those found in children of school ages can be distinguished uniformly throughout the age range.

Analyses of the Bakwins' and Low's data confirm these distinctions. The types are probably determined by the relative development of the long bones, muscle and fat.

The consistency of the individual type values has been assessed over an interval of 3–5 years at various age levels. The type consistency is low in infancy and increases throughout the school ages largely because the variance of the first measurements contributes an increasingly greater part to the variance of the second measurements in older children.

Factor analysis of growth increments showed a distinction into relatively greater length, girth or breadth development similar to the types of attained measurements, but the type growth was less important than general growth and showed little consistency from one period to another. Within the same social and nutritional levels the type growth did not appear to be related to the physical type.

The type consistency found could be explained in terms of growth randomly superimposed on the initial type figure except where the attained types were also related to social or nutritional influences. In these cases the types also showed a consistently different growth pattern.

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Health) and I wish to acknowledge his contribution in this respect and also in the helpful suggestions he has made at each stage.

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TYPICAL AND ATYPICAL CHANGES IN THE SOFT TISSUE DISTRIBUTION DURING CHILDHOOD

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INTRODUCTION

IN anthropometric studies on body build and physical development of white children in New Jersey (Kornfeld '47, '53, '54, '55) we tried to analyse the changes occurring in the distribution of the subcutaneous fat tissue during childhood.[1] The same selection of measurements and the same technique was used which we had developed for earlier studies in Vienna (Kornfeld and Schüller '30), with the exception that an anthropometric caliper was used instead of the small micrometer used before. Results obtained this way may not be as accurate as those obtained by the more recently developed methods of examination (measuring skinfolds with special calipers which allow a constant pressure,—Franzen '29, McCloy '36, '38, Brožek '53,—and roentgenometric determination of subcutaneous fat layers, Garn '55a, Stuart, Hill and Shaw

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[1] The following measurements were taken on these children since 1940: body length, stem length, weight, head circumference, supramamillary chest circumference; circumferences of wrist, forearm, arm, and calf; hand length, hand breadth and middle finger length. Since 1950 the following were added: fronto-occipital and biparietal diameters of the head, chest circumference at the level of the xiphoid, foot length, foot breadth and bimalleolar diameter. Finally in 1952 we resumed the soft tisue measurements, which are discussed in this paper and which we had not used since our studies in Vienna.

Longitudinal studies were considerably handicapped by the fluctuating character of our pediatric practice. Even in the limited number of cases which were regularly examined over a long period of time, the first group of measurements enumerated above could be followed on the same individual for a period of 14 years; the second group for 6 years, at best; and the soft tissue measurements for only four years.

'40, Stuart and Dwindell '42, Stuart and Sobel '46, Reynolds '51). The circumstances under which these examinations were performed made it necessary, however, to use simple methods. The data for normal individuals were collected during office hours on children who came for periodic health examinations. Pathologic cases were examined in hospitals, where we had to bring our equipment with us. In both cases examinations had to be made with as little disturbance as possible in office or hospital routine, and with limited equipment. The anthropometric caliper was used for other measurements anyhow; X-ray studies would not have been feasible, and the special calipers were not available. The material presented in this paper may prove, however, that our findings fit well into those obtained by other research workers who could apply more refined methods. We believe that our method allows an analysis of some characteristic features in the distribution of subcutaneous soft tissues, as part of a developmental appraisal, in a comparatively simple manner.

MATERIAL AND METHODS

Our standard values were derived from normal healthy white children, living in metropolitan and suburban New Jersey, predominantly of middle class families. The racial background was not homogeneous: about ⅔ of the children were of Jewish descent, the remaining of Anglo-Saxon, German, Scandinavian, or Slavic origin. It could be shown, however, that body build and physical development of these children did not differ essentially from that of other groups, which are assumed to be typical for the average white population in the United States (Kornfeld '54).

Measurements on skinfolds were taken in the following areas: on the chest about one inch below the middle of the right clavicle; on the abdomen about midway between navel and iliac crest; on the back about one inch medial to the inner border of the right scapula. Subcutaneous tissue masses on the cheeks were measured in the following manner: the bizygomatic diameter was determined over the most prominent points of the zygomatic arch without any pressure, so that the surface of the skin was not dented. Then the measurement was repeated at the same spot, while the caliper was pressed gently against the underlying bone. The difference between the two measurements was obtained, indicating the thickness of the compressible or displaceable subcutaneous masses.

FINDINGS

Mean values of the soft tissue measurements, as obtained by the examination of normal healthy children, are reported in table 1a-d. This table contains also the numbers of children examined in each age group, the medians, the range of variation, and the standard deviations. Figure 1 presents the average values for boys and girls with the omission—for economy of space—of alternating age groups.

TABLE 1

Mean values, medians, range of variations and standard deviations for soft tissue measurements in boys and girls

A. CHEEKS

	BOYS						GIRLS					
AGE	N	Mean	Med.	Min.	Max.	S.D.	N	Mean	Med.	Min.	Max.	S.D.
Newborn	50	7.7	7.5	5	12	1.9	50	8.6	8.3	5	13	1.9
3 months	50	9.4	9.7	5	13	2.0	60	9.5	9.5	6	15	1.8
6 "	50	10.1	10.1	5	14	1.9	60	10.1	10.0	6	10	1.8
9 "	40	10.4	10.1	7	15	1.8	50	10.2	10.2	7	15	1.3
12 "	40	9.9	9.9	5	16	2.1	40	9.8	10.1	6	14	1.9
18 "	18	10.0	9.9	7	14	1.6	14	10.8	11.0	7	13	1.6
2 years	40	9.5	9.5	6	13	1.6	30	9.2	9.3	5	12	1.6
2½ "	30	9.5	9.4	6	14	1.7	20	8.4	8.5	5	11	1.6
3 "	50	9.1	9.0	5	14	1.9	45	9.0	9.0	6	12	1.5
3½ "	40	8.7	8.5	6	12	1.4	35	8.7	8.9	5	12	1.7
4 "	50	8.3	8.2	5	13	1.6	50	8.2	8.0	5	11	1.6
4½ "	40	8.0	7.8	5	13	1.7	30	8.2	8.3	4	13	2.1
5 "	50	7.6	7.8	5	12	1.6	50	8.0	8.0	3	12	2.0
5½ "	40	7.7	7.5	5	12	1.8	30	7.5	7.2	5	11	1.6
6 "	50	7.6	7.4	5	13	2.0	45	7.4	7.0	4	12	1.9
6½ "	40	7.7	7.5	5	12	1.7	40	7.2	7.0	4	11	1.6
7 "	40	7.4	7.3	5	10	1.3	50	7.4	7.2	4	12	2.0
7½ "	30	7.4	7.5	5	11	1.6	40	7.3	7.0	4	14	2.1
8 "	36	7.4	7.5	3	10	1.5	48	7.2	6.7	4	11	1.8
8½ "	30	7.6	7.5	5	10	1.4	30	7.2	7.3	4	11	1.6
9 "	30	7.2	7.1	5	11	1.4	49	7.5	7.6	3	13	2.1
9½ "	30	6.8	6.7	5	11	1.4	36	7.4	7.3	4	13	2.1
10 "	40	6.9	6.7	3	11	1.7	40	6.7	6.7	4	13	1.9
10½ "	35	6.5	6.5	4	9	1.1	29	6.5	6.8	3	11	1.9
11 "	30	6.8	6.8	4	10	1.7	30	6.9	6.8	5	11	1.3
11½ "	30	7.1	6.7	5	12	1.6	18	6.9	6.5	4	11	2.1
12 "	30	6.7	6.6	4	11	1.7	18	6.3	6.2	4	9	1.1
12½ "	26	7.4	7.2	5	12	1.5	14	6.9	7.1	4	11	1.7
13 "	23	7.0	6.3	5	11	1.8	12	6.7	6.2	5	9	1.5
13½ "	14	6.4	6.2	4	10	1.6	10	6.5	6.5	5	9	1.4
14 "	15	6.5	6.7	4	9	1.4	4	6.5	6.0	5	9	—
14½ "	7	5.3	5.0	3	7	—						
15 "	10	6.0	6.0	4	8	—						
15½ "	5	5.0	4.7	4	7	—						
Total	1139						1077					

TABLE 1 (Continued)

B. CHEST

AGE	BOYS					GIRLS				
	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.9	3.7	3	7	1.0	4.0	3.9	3	6	0.8
3 months	6.7	6.4	3	12	2.0	7.0	6.3	3	14	2.3
6 "	6.3	5.1	4	10	1.6	7.4	7.1	3	15	2.5
9 "	6.0	5.5	4	9	1.5	6.2	5.9	4	12	1.8
12 "	5.5	5.2	3	9	1.4	6.0	5.7	4	11	1.7
18 "	5.9	5.8	3	10	2.0	6.2	6.0	4	9	1.6
2 years	6.2	6.0	3	10	1.7	6.6	6.5	4	11	1.9
2½ "	6.2	6.0	3	10	2.2	7.0	6.7	4	12	2.2
3 "	6.3	6.2	3	11	1.8	7.7	7.5	4	15	2.3
3½ "	6.0	5.9	4	9	1.5	7.5	7.1	3	16	2.2
4 "	5.9	5.8	2	11	1.8	7.2	6.6	3	14	2.6
4½ "	5.4	4.9	3	9	1.5	7.2	6.2	3	22	3.9
5 "	5.8	5.1	3	15	2.4	7.3	6.7	3	18	2.9
5½ "	6.5	5.2	3	20	3.5	6.9	6.5	3	16	2.8
6 "	6.3	5.1	3	19	3.5	7.7	6.5	3	26	3.0
6½ "	6.5	5.2	3	23	3.9	8.0	6.7	4	18	3.7
7 "	5.9	5.1	3	18	3.2	8.1	7.2	3	21	3.4
7½ "	6.1	4.9	3	19	2.3	8.9	7.8	4	22	4.2
8 "	6.2	5.1	3	24	2.9	8.8	7.7	3	20	3.9
8½ "	7.1	5.3	3	24	4.5	9.3	8.5	4	17	3.6
9 "	7.0	5.4	3	19	4.0	10.4	8.9	3	28	5.1
9½ "	7.6	6.2	2	20	4.3	10.9	11.0	4	20	4.7
10 "	7.5	6.0	3	20	4.4	10.2	9.0	4	23	5.0
10½ "	8.1	6.0	3	28	5.7	11.0	8.6	4	22	5.4
11 "	7.8	6.0	3	19	4.4	10.6	8.4	5	28	4.9
11½ "	9.7	7.0	3	15	6.5	9.5	9.0	4	18	3.6
12 "	9.9	8.0	4	25	5.9	10.2	8.8	5	18	3.9
12½ "	10.0	8.5	3	20	5.5	9.4	9.0	5	18	3.7
13 "	9.1	6.8	3	25	5.6	11.2	10.5	6	19	4.0
13½ "	7.6	6.7	4	16	3.8	10.6	10.5	5	15	2.9
14 "	8.3	5.3	4	20	5.2	} 10.2	9.5	7	15	—
14½ "	6.9	5.7	4	16	—					
15 "	7.5	5.5	4	15	—					
15½ "	6.0	6.0	5	7	—					

TABLE 1 (Continued)

C. ABDOMEN

AGE	BOYS					GIRLS				
	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.2	3.1	2	5	0.6	3.1	3.1	2	4	0.4
3 months	5.6	5.5	3	8	1.3	6.4	6.4	3	10	2.5
6 "	5.3	4.9	3	9	1.5	6.1	5.9	3	10	1.8
9 "	5.1	4.7	3	9	1.4	5.5	5.1	3	10	1.4
12 "	4.8	4.7	3	9	1.4	5.4	5.2	3	9	1.3
18 "	4.8	4.4	3	8	1.4	4.8	4.8	3	6	0.9
2 years	4.7	4.7	3	7	1.2	5.0	4.9	2	8	1.4
2½ "	4.2	4.2	3	6	0.9	5.2	5.2	3	8	1.6
3 "	4.3	4.1	3	8	1.2	5.4	5.0	3	11	1.7
3½ "	4.4	4.1	3	9	1.4	5.1	4.6	3	10	1.8
4 "	4.0	3.9	2	7	1.0	4.8	4.3	3	10	1.8
4½ "	4.0	3.8	3	8	1.2	5.5	4.1	3	25	4.3
5 "	4.6	3.9	2	9	1.4	5.3	4.0	2	20	3.0
5½ "	4.5	4.1	2	10	1.9	5.1	4.3	3	12	2.3
6 "	4.6	3.8	3	18	2.5	5.6	4.5	3	14	2.7
6½ "	4.9	3.7	2	22	3.9	6.0	5.1	4	11	2.4
7 "	4.2	3.8	3	13	1.8	6.1	5.3	2	15	2.8
7½ "	3.9	3.5	2	9	1.5	7.4	6.1	2	22	4.0
8 "	4.5	4.0	3	11	1.8	7.5	6.0	3	18	4.1
8½ "	4.6	4.0	3	13	2.1	8.7	7.5	3	20	4.5
9 "	5.2	3.9	3	17	3.4	9.3	8.3	3	25	5.2
9½ "	5.6	4.4	2	14	3.2	9.7	8.0	3	21	5.7
10 "	5.4	4.6	2	14	2.9	9.3	8.5	3	20	4.8
10½ "	6.8	4.8	2	27	5.3	8.0	8.0	4	32	6.2
11 "	6.2	4.7	3	15	3.7	10.1	8.0	3	28	5.8
11½ "	7.8	6.0	3	20	5.0	9.9	8.2	4	20	4.7
12 "	7.8	6.5	3	19	4.5	11.4	10.0	5	21	4.9
12½ "	8.7	5.8	3	24	5.7	10.5	9.8	4	18	3.8
13 "	8.8	5.4	3	24	5.8	12.8	12.5	5	22	5.7
13½ "	6.9	5.2	3	16	4.0	13.4	13.7	8	22	4.4
14 "	9.8	6.0	3	28	7.2	15.2	15.5	12	18	—
14½ "	8.0	6.0	3	20	—					
15 "	9.9	6.0	4	21	—	—	—	—	—	—
15½ "	7.6	7.0	5	12	—	—	—	—	—	—

TABLE 1 (Continued)

D. BACK

AGE	BOYS					GIRLS				
	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.8	3.7	3	7	0.8	4.1	4.1	3	5	0.7
3 months	5.7	5.6	4	10	1.1	6.1	6.0	4	10	1.5
6 "	5.9	5.6	4	10	1.2	6.4	6.0	3	10	1.5
9 "	6.3	6.0	4	9	1.3	6.6	6.8	4	9	1.6
12 "	6.4	6.3	4	10	1.3	6.8	6.8	4	10	1.6
18 "	7.2	7.3	5	9	1.3	7.1	6.7	5	10	1.5
2 years	6.0	5.7	3	9	1.5	6.3	5.9	4	11	1.9
2½ "	5.9	5.8	4	9	1.4	6.4	5.7	4	12	2.0
3 "	5.8	5.7	3	10	1.5	6.4	6.2	4	12	1.6
3½ "	5.4	5.3	3	9	1.2	5.8	5.7	3	9	1.3
4 "	5.4	5.3	3	9	1.3	5.9	5.3	3	13	1.8
4½ "	5.1	4.9	3	9	1.3	6.2	5.2	3	17	2.8
5 "	5.3	5.0	3	9	1.5	6.2	5.7	3	15	1.9
5½ "	5.7	5.1	3	12	1.9	6.1	5.7	4	12	1.7
6 "	5.5	5.0	3	12	2.3	5.9	5.3	3	13	2.0
6½ "	6.1	5.4	3	14	2.4	6.1	5.5	4	12	2.1
7 "	5.5	5.0	4	12	1.4	6.3	5.7	3	15	2.3
7½ "	5.1	4.9	3	10	1.4	6.6	5.4	3	16	2.9
8 "	5.5	5.1	4	9	1.4	6.3	5.3	4	15	2.5
8½ "	5.5	5.1	4	12	1.8	6.9	6.5	4	11	1.9
9 "	5.6	5.2	4	12	1.9	7.1	6.5	4	23	3.4
9½ "	5.7	5.4	3	11	1.8	7.7	7.0	4	18	2.8
10 "	5.7	5.2	3	10	1.7	6.6	6.2	4	13	1.9
10½ "	6.0	5.1	3	20	3.0	7.2	6.4	4	15	2.5
11 "	5.8	5.7	4	12	1.7	7.2	6.5	4	14	2.8
11½ "	6.1	5.6	4	13	2.0	7.2	7.5	5	9	1.3
12 "	7.0	6.2	4	13	2.3	7.6	7.3	4	14	2.4
12½ "	7.0	6.2	4	16	2.8	7.6	7.7	5	10	1.1
13 "	7.5	6.3	4	17	3.3	8.2	8.0	5	12	2.0
13½ "	6.5	6.1	4	11	1.8	8.5	8.2	7	12	1.5
14 "	7.1	5.4	4	12	2.7	} 9.5	9.5	9	16	—
14½ "	7.1	6.7	4	13	—					
15 "	6.9	6.2	5	13	—	—	—	—	—	—
15½ "	7.0	7.3	5	8	—	—	—	—	—	—

Analysis of the figures in these tables reaffirms earlier reports in many points. (For a review of the earlier literature see Reynolds '51). Higher mean values for girls were found in the chest measurements in all age groups with the exception only of the 11½ and 12½ year olds; on the abdomen in all age groups except the newborn and the 18 month olds, where the measurements were equal or nearly equal in both sexes; on the back in all age groups except for the 18 month and 6½ year olds, where again the measurements were equal or almost equal. The preponderance of the mean values in the females was least regular in the cheeks, where higher means in boys were found for the age groups of 2½, 6½, 8½, 12, 12½, and 13 years and equal or almost equal mean values in several other age groups.

The difference between the soft tissue measurements in boys and girls which are seen in the mean values for each age group are even more evident if we analyse the distribution of the individual measurements in each age group. For reason of economy of space we do not include tables of these distributions in this publication. We would like to mention, however, that such distribution tables explain some of the irregularities seen in the tabulation of the mean values. The highly asymmetric distribution of the individual measurements, which is most evident in these distribution tables, is a well known phenomenon. Minus variants may extend from the mean to a low value representing the thickness of the skin itself with a minimum of subcutaneous tissue; plus variants may extend into extremely high values with execessive fat accumulation. This skewed character of the distribution of soft tissue measurements can also be seen in the difference between the means and the medians. The medians may be considered as even more representative for the typical changes in soft tissue distribution during childhood than the means.

There are also differences in the variability of the soft tissue measurements between boys and girls. These differences are evident when we compare the standard deviations or, even better, when the coefficient of variation (100 times the standard deviation divided by the mean) is used for comparison. In the newborn the variability appears to be slightly higher in boys than in girls for all four measurements. The variability for the cheeks stays slightly higher in boys during the first year; during the second and third year there is no steady difference; from the fifth to the 13th year the variability is higher in girls, during the 14th year higher in boys. The variability of the chest tissues is slightly higher in girls of 6 to 12 months, markedly higher in boys from the 6th year up to the age of 14. Variability of the abdominal fat masses is higher in girls from two to 8 years, in boys from 9 to 14. Variability of the skinfolds on the back is higher in girls in most age groups until 11 years, higher in boys from 12 to 14.

Changes in the distribution of soft tissue masses during childhood have been described since the first studies of skinfold measurements in children were published. Neuman ('12) reported the faster increase in abdominal fat in girls. He also tried to find quantitative relations between changes in skinfold thickness and changes in body weight, as Oeder ('10) had done for adults. Batkin ('15) described typical differences in skinfold thickness for 8 different regions but assumed from his findings a rather persistent pattern for these regional differences throughout childhood. Peiser ('21) compared the findings on skinfolds and their changes with the individual Pelidisi Index (Pirquet's index for the nutritional state). In our studies in Vienna the different character of the average curves for the soft tissue in the four regions was demonstrated. The most exhaustive study of this topic is Reynolds' monograph ('51), in which a thorough discussion of all earlier research in this field may also be found.

In our present studies on New Jersey children the following changes were found to be typical: mean values for the soft tissue masses in all four regions increase rapidly during the first 6 months of life, in boys as well as in girls. The mean values for the cheeks stay high until about 18 months and decrease slowly thereafter. Mean values for chest decrease slightly at the end of infancy, stay low from one to 5 years, then increase to reach the highest values in boys at 11-13 years, in girls at 9-14 years. After 14 years mean values decrease in both sexes. Medians for the chest show a second (pre-puberty) increase in boys from 11-13, in girls from 9-14 years. Mean values for abdomen stay low in boys from one to 9 years, in girls from one to 7 years, after which period an increase takes place faster in girls, slower and less markedly in boys. Changes in the soft tissue masses on the back are similar to those on the abdomen but less pronounced.

The described changes show a specific pattern of development for each of the four measurements. The difference in these developmental patterns results in typical changes in the relation between the measurements taken in the four different regions. These changes can be illustrated by graphs based upon the mean values for the different age groups, as shown in Figure 1. The following typical changes can be read from these graphs: at birth the mean value for cheeks is by far the highest, the value for abdomen the lowest; the values for chest and back are in between, near to each other and only slightly above the mean for abdomen. These relations stay rather similar through the first two or three years of life in boys as well as in girls. The whole level of the graphs reflects the increase of the soft tissue masses during the first months of life and the following slow decrease during the second, third and fourth year. Around an age of 5-7 years the profiles as a whole reach the lowest level; at the same time means for the skinfold measurements become nearer to the level of the cheek measurements, which are decreasing. From 6 to 10 years there is a difference in these soft tissue profiles between boys and girls: the girls show a very definite pattern with the chest values becoming more and more elevated; the values for abdominal fat follow with a slightly slower increase, means for cheeks and back lagging behind. At 12-14 years the means for abdominal soft tissue masses surpass the values for the chest, thus climbing to the top of the profile. The relation between the two lower values, cheeks and back, changes so that finally the cheeks have the lowest mean value with the back tissue gradually increasing. In boys the changes are slightly different: The means for chest surpass the means for the cheeks later and more slowly than in girls. The increase in abdominal tissue masses

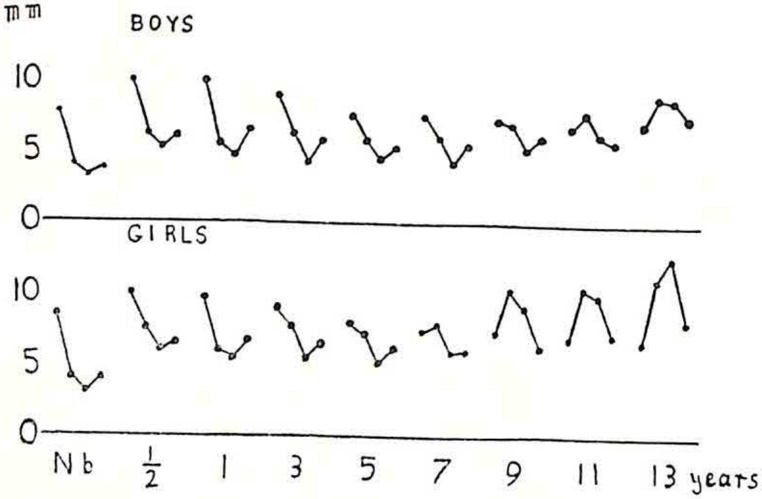

FIG. 1. AVERAGE CHANGES FROM THE NEWBORN TO THE AGE OF 13 YEARS. LINES CONNECT DOTS REPRESENTING SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK, IN THAT ORDER.

is also delayed and brings the mean values for abdomen above those for the chest in boys only at 14 years.

Similar changes as depicted in these profiles based upon mean values for each age group can be demonstrated in series of graphs based upon longitudinal studies on individuals. Figure 2 gives examples for two infants, observed from birth to the age of three years. We see in both children increase of the soft tissue masses during the first and decrease during the second year. At the same time we notice how certain individual features of the soft tissue distribution are rather persistent: high values of the cheek tissue in the one case (figure 2a), comparatively high values of the back tissue in the second case (figure 2b). Unusually high values for the cheeks may persist longer, as shown in figure 3a for a boy at the ages from two to 5 years. By contrast figure 3b depicts the condition in a girl with persistently high values for chest tissue, gradual increase of all soft tissue masses from 2½ to 4 years (moderate obesity), and slimming in the fifth year. Figure 4a shows gradual decrease of soft tissue masses in a girl during the 5th and 6th year, with a sudden increase of fat on the chest in the 7th year. A similar increase of subcutaneous tissue during the 6th, 7th and 8th year, fol-

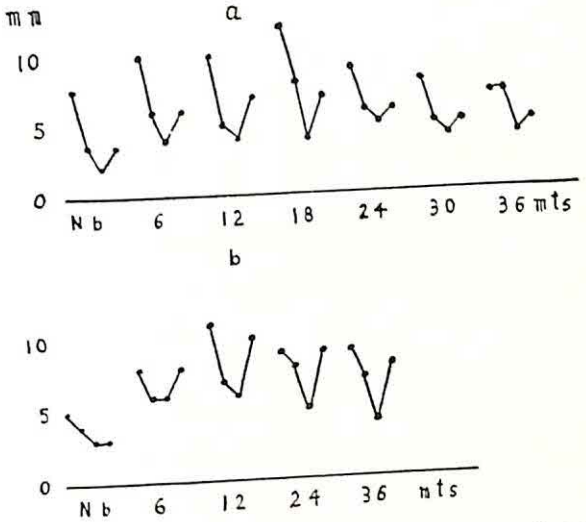

FIG. 2. a AND b. INDIVIDUAL CHANGES IN TWO INFANTS OBSERVED THROUGH THE FIRST THREE YEARS OF LIFE: SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK.

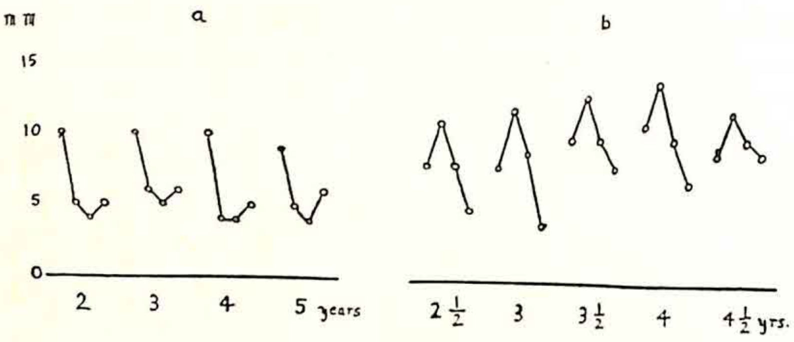

FIG. 3. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. BOY WHO SHOWS UNUSUALLY HIGH VALUES FOR THE CHEEKS AT THE AGES OF 2, 3, 4 AND 5 YEARS. b. GIRL WITH PERSISTENT HIGH VALUES FOR CHEST; MODERATE OBESITY DEVELOPING DURING FOURTH YEAR.

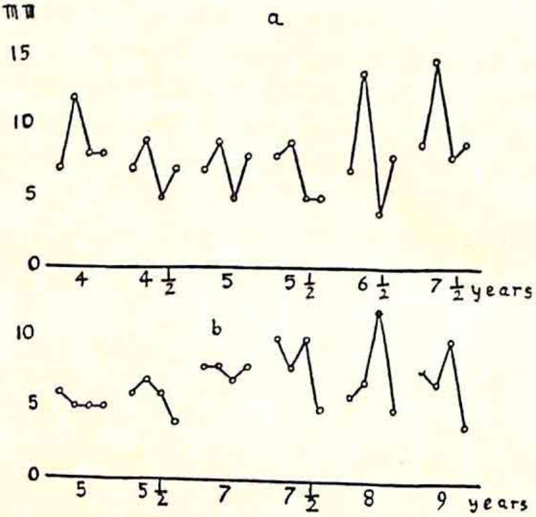

FIG. 4. SOFT TISSUE MASSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. GIRL WITH DECREASES IN ALL MASSES DURING THE FIFTH YEAR AND AN INCREASE IN CHEST FAT IN THE SEVENTH AND EIGHTH YEAR OF LIFE. b. GIRL WITH INCREASES FROM 5 TO 8 YEARS AND SLIGHT DECREASE AT 9 YEARS.

lowed by a slight decrease during the 9th year in shown for another girl in figure 4b. Persistent slenderness through age 9½ to 13½ is shown for a boy in figure 5a, while figure 5b depicts the conditions in a girl

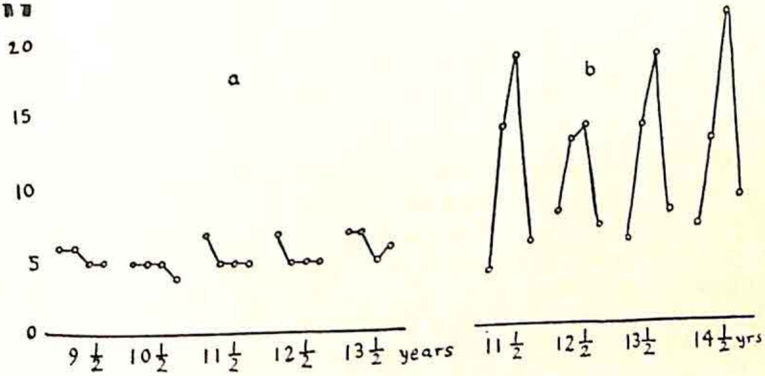

FIG. 5. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. BOY, PERSISTENTLY SLENDER FROM 9½ TO 13½ YEARS. b. OBESE GIRL WITH TRANSITORY SLIMMING DURING 13TH YEAR.

from 11½ to 14½ years. A transitory decrease of the soft tissue masses during the 13th year interrupts here an otherwise rather persistent pattern of moderate obesity. Figure 6 ilustrates the case of a boy with a similar transitory period of comparative slenderness around the age of 12 years interrupting an otherwise steady increase of the soft tissue

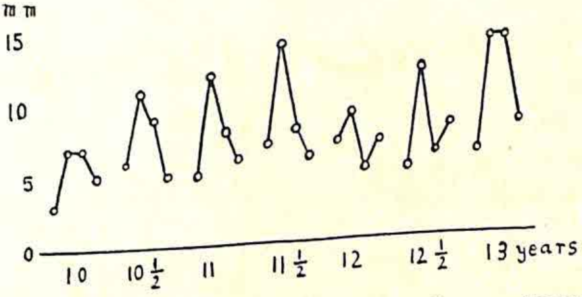

FIG. 6. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. BOY WITH MODERATE INCREASES IN FAT FROM 10 TO 11½ YEARS FOLLOWED BY PREPUBERTAL SLIMMING AND INCREASES AGAIN DURING THE 13TH YEAR.

masses from age 10 to age 13. Figure 7 shows the development of the soft tissue masses in a pair of identical twins for the period from 8 to 10 years. The figure consists of 5 pairs of graphs: the first graph in each pair depicts the measurements of the one twin, while the second graph of each pair depicts the measurements of the other twin, obtained at the same time. The graphs illustrate the similarity of the profiles for the two twins in general and at the same time show some persistent individual features in minor details in which the twins differ.

All these changes become even more meaningful when the development of the soft tissue masses is compared with other measuremnts, taken at the same time. To illustrate this, figure 8 shows two cases of moderate obesity and table 2 contains excerpts of the anthropometric findings for the same period. The first case is that of a boy who gained very rapidly during the second half of the 9th and during the second half of the 11th year. During these two periods of rapid weight gain arm circumference and abdominal tissue show rapid increases, tissues on cheeks and back slight increase, while the measurements on the chest behave somewhat paradoxically, decreasing just during the periods of fast weight gain and increasing during periods of considerably slower weight gain. In the second case (figure 8b and table 2b) we find a boy with longitudinal growth steadily above average for his age, weight persistently above average for his height, arm circumference persistently high above average, and wrist circumference moderately high. The measurements of superficial soft tissue masses, however, show persistently average values in the cheeks, and moderately elevated values for the back. Thickness of the skinfolds on the chest was very high at 9½ and 11 years, but came

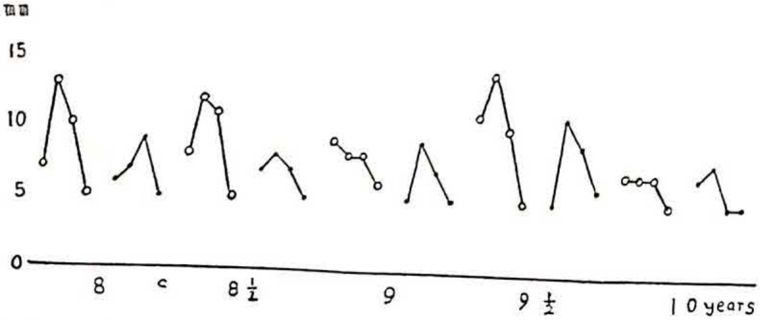

Fig. 7. Soft Tissue Thicknesses on Cheeks, Chest, Abdomen and Back in a Pair of Identical Twins. For Each Age from 8 to 10 Years the Graph with Open Circles Depicts the Condition Found in One Twin (Barbara), The Second Graph, with Dots, Depicts that in the Other (Beverly). Beverly is Slightly Thinner Throughout These Years; The Trend of Changes from Year to Year, however, Shows Great Similarities for Both Girls.

down to moderate elevated values in the 13th and 14th years. Skinfolds on the back were moderately high at 9½ and 11 years, increased considerably at 12½ years, after which they decreased in thickness so far that, at 14 years, an average level was reached. Analysis of the changes in the soft tissue distribution by observations of this kind may be helpful in the management of obesity.

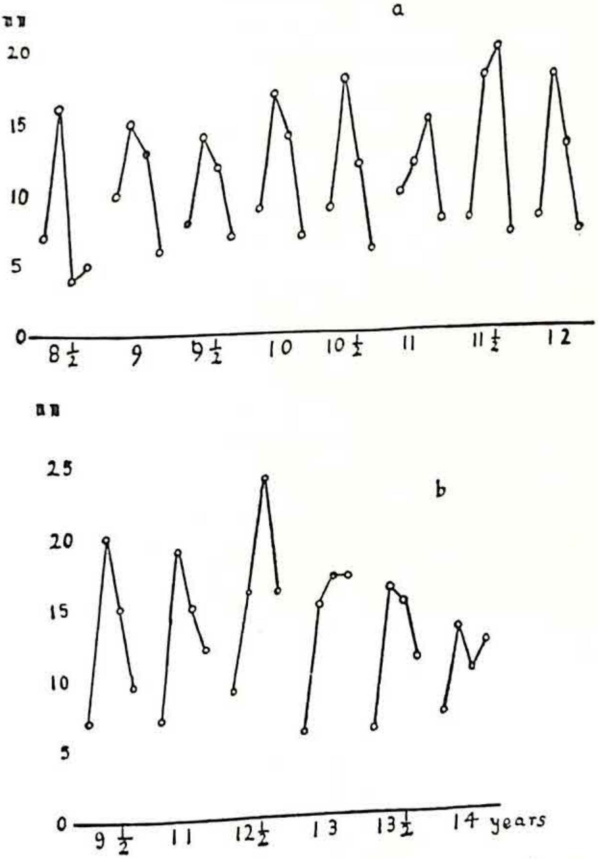

FIG. 8. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK IN TWO CASES OF OBESITY IN BOYS. SOME ADDITIONAL ANTHROPOMETRIC DATA ARE REPORTED IN TABLE 2.

In a similar way such studies may help in the evaluation of the development of premature infants. Such infants show, at least in the beginning, a marked deficiency in soft tissue development. It is interesting to see how this deficiency in soft tissue development is corrected and to compare this improvement with other features of the physical develop-

TABLE 2

Some measurements obtained in repeated examinations on 2 boys with moderate obesity

AGE	BODY LENGTH		WEIGHT			WRIST			ARM			SOFT TISSUE THICKNESS			
		Average for		Average for			Average for			Average for					
years	cm	Age cm	kg	Age kg	Height kg	mm	Age mm	Height mm	mm	Age mm	Height mm	Cheek mm	Chest mm	Abd. mm	Back mm
a) Steven H.															
8½	128.5	132.0	31.5	28.70	27.0	134	130	128	223	191	187	7	16	4	5
9	131.5	134.5	34.25	30.30	28.50	140	131	130	238	196	190	10	15	12	6
9½	133.5	137.0	34.45	32.00	29.80	140	133	131	235	201	194	8	14	12	7
10	135.0	139.0	35.30	33.70	30.60	143	135	131	235	205	197	9	17	14	7
10½	137.5	141.5	36.30	35.50	32.00	143	137	133	235	210	203	9	18	12	6
11	141.0	144.0	41.40	37.40	35.20	145	139	137	270	215	209	10	12	15	8
11½	143.0	146.5	42.40	39.50	36.65	147	141	139	265	220	214	8	18	20	7
12	146.0	149.5	41.70	41.75	39.05	147	143	141	258	225	220	9	18	13	7
b) Paul A.															
9½	144.0	136.5	44.85	32.00	37.40	145	133	139	236	201	215	7	20	14	9
11	153.0	144.0	55.50	37.40	44.35	155	139	146	285	215	226	7	19	15	12
12½	161.0	152.0	62.25	43.60	50.65	157	145	152	285	228	235	9	16	24	16
13	164.0	156.0	68.85	46.50	53.00	165	149	155	300	232	237	6	15	17	17
13½	168.5	159.5	68.00	49.30	56.40	165	150	159	290	234	240	6	16	15	11
14	172.5	162.5	71.60	52.50	60.80	167	154	165	305	236	250	7	13	10	12

ment in prematurely born infants. The status of the soft tissue masses in two premature infants from the age of one month up to two years is illustrated in figure 9a and b. Some additional anthropometric data are reported in Table 3.

Melanie R. (figure 9a and table 3a), first child of a diabetic mother, who had one spontaneous abortion before, was delivered after about 35 weeks of an uneventful pregnancy by cesarean section, with a birth weight of 3 lbs. 3 oz. (1450 grams). She was discharged from the hospital at four weeks of age in good general conditions with a weight of 1700 grams and body length of 43 cm. Soft tissue on the cheeks was slightly below average, skinfolds on chest, abdomen and back very low. At about two months she had reached the average body length and weight of a normal full term newborn girl. Longitudinal growth progressed steadily, but stayed below the average for the age. Body weight increased rapidly, was soon above average for the child's body length and starting with 9 months even above the average of girls of her age. Circumference of the wrist reached the average for age at 9 months and then stayed near the average values. The arm circumference increased in a similar way as the wrist. All soft tissue measurements were still below average at three months, cheeks only slightly, the three skinfolds

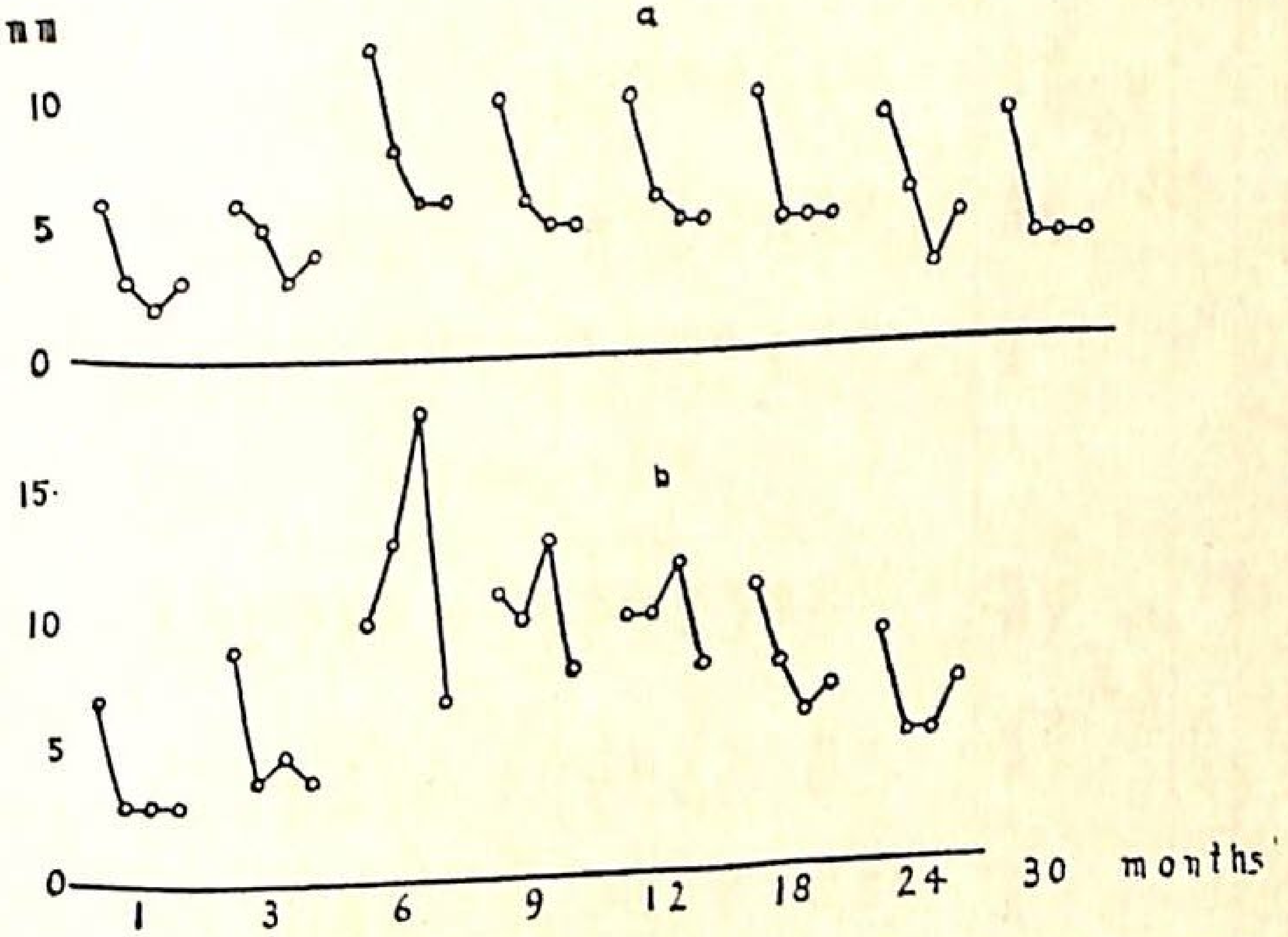

FIG. 9. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK IN TWO INFANTS BORN PREMATURELY. SOME ADDITIONAL ANTHROPOMETRIC DATA ARE REPORTED IN TABLE 3.

TABLE 3

Some measurement obtained in repeated examinations of 2 premature infants

AGE	BODY LENGTH		WEIGHT			WRIST			ARM			SOFT TISSUE THICKNESS			
		Average for		Average for			Average for			Average for					
months	cm	Age cm	kg	Age kg	Height kg	mm	Age mm	Height mm	mm	Age mm	Height mm	Cheek mm	Chest mm	Abd. mm	Back mm
a) Melanie R.															
1	43.0	52.5	1.70	3.80	2.00	54	76	—	63	100	—	7	2.5	2.5	2.5
3	51.0	59.5	3.50	5.60	3.50	69	86	73	84	119	90	9	4	5	4
6	60.0	66.0	6.90	7.50	5.75	90	95	86	120	136	113	10	13	18	7
9	67.5	70.0	9.10	8.60	7.95	100	100	96	140	144	133	11	10	13	8
12	72.0	74.0	10.90	9.70	9.20	107	102	101	150	148	141	10	10	12	8
18	78.0	80.5	12.50	11.10	10.60	103	103	102	165	151	146	11	8	6	7
24	82.5	86.0	12.60	12.25	11.90	105	104	103	152	153	151	9	5	5	7
b) John S.															
1	42.5	53.5	1.75	4.05	2.00	57	79	—	61	97	—	6	3	2	3
3	50.5	60.5	3.60	6.00	3.40	79	90	71	94	119	85	6	5	3	4
6	60.5	67.5	6.40	8.10	6.00	90	100	90	122	136	119	12	8	6	6
9	66.5	71.5	7.70	9.40	7.80	102	105	98	135	144	132	10	6	5	5
12	71.0	75.5	9.10	10.40	9.25	102	107	104	148	148	143	10	6	5	5
18	76.5	82.0	9.85	11.80	10.60	100	108	107	145	151	148	10	5	5	5
24	83.5	87.5	11.10	12.90	12.10	101	109	108	148	153	151	9	6	3	5
30	88.5	92.0	11.80	13.85	13.10	102	110	109	143	155	153	9	4	4	4

considerably. From 6 to 24 months we find near average values for cheeks and back. Skinfolds on chest and abdomen were considerably above average at 6-12 months, nearly average at 18 and 24 months.

John S. (figure 9b and table 4b) was delivered 8 weeks before term, by cesarean section because of premature separation of the placenta, with a birth weight of 3 lbs 9½ oz. (1600 grams). At 10 days his weight was down to 1360 grams. At the age of one month his weight of 1750 grams was approximately average for his body length of 42.5 cm. and this relation stayed about the same until the age of 12 months. After the first year the weight increased much more slowly, so that we find a persistent underweight for his height from 18 to 30 months, and a body length below the average for his age all through this time. Corresponding to this underweight we see the wrist and arm circumferences steadily below average, with the exception of an average value for the arm circumference at the age of 12 months. At the age of one month and again at the age of three months all soft tissue measurements were considerably below average. At 6 months, however, the figures for cheeks and chest were above average, the figures for abdomen and back around average. After this period the values for cheeks, chest and abdomen stayed around the average, the skinfolds on the back slightly below average.

Analysis of the soft tissue development in these two prematurely born infants shows the initial underdevelopment of the soft tissue masses corrected by about 6 months. While other features of delayed physical development may persist longer, the pattern of soft tissue distribution after the 6th month shows no after effect of the original deficiency. Individual differences, based apparently upon genetic factors, show up in the soft tissue profiles of prematurely born infants after the 6th month just as they appear in full term infants.

DISCUSSION

The studies reported here present a comparatively simple method for the evaluation of the soft tissue distribution in children of different age groups. Some changes in this distribution are characteristic for the normal development of the average child, with variations occurring within a normal range. Other more marked variations occur in borderline cases of normality, as in prematurity or in moderate obesity. Still more pronounced deviations have been observed in pathologic conditions; the discussion of such cases, however, was not included in this paper.

The method described here had been developed during studies on children in Vienna. It was used there to analyse the effect on the nutritional status of open air treatment in children with inactive tuberculosis (Kornfeld and Schüller, '31) and also to follow the changes in the status of such children after discontinuation of such treatment (Kornfeld and Orosz, '31). These studies revealed that the considerable weight gain in such periods and the loss of weight usually following such accelerated gain is accompanied by changes in the soft tissue distribution, but that these changes show considerable individual variations.

The significance of individual differences in the soft tissue distribution in children has been discussed by Reynolds ('51) on the basis of roentgenometric studies on children of the Fels Institute Research Project. Among his examples of individual peculiarities are also two pairs of twins and three cases of obesity. Fat distribution in children with pathologic disturbances other than obesity has not been studied extensively. Exceptions were the studies of two cases with lipodystrophy by Feer ('15) and a paper by Batkin ('15) who described changes in skinfold measurements in different pathologic conditions.

The role of relative fat patterns as an individual characteristic has been analysed recently in adults by Garn ('55a). Roentgenometric measurements of fat thickness in 9 different areas were converted into standard score values. On this basis profiles of the fat distribution were drawn, which show very definite individual characteristics. Garn shows that these individual fat patterns are of a considerable consistency even through periods of enforced weight loss. A similar deduction may be obtained from our graphs for normal as well as for obese children and also from our earlier observations on children during and after open air treatment. In a more recent paper Garn ('55b) emphasizes the advantage of relative patterns based upon standard scores, as compared with profiles based upon absolute measurements. We used similar profiles, based upon variation classes of selected measurements, for the graphic illustration of body build and physical development in earlier studies (Kornfeld '27 and '28). We hesitated, however, to use classification by standard deviations in the construction of profiles for the soft tissue distribution because of the highly asymmetric distribution of the individual values.

SUMMARY

1. A method of evaluation and graphic illustration of the soft tissue distribution in children is described. It can be used comparatively easily within a general anthropometric examination. The method comprises skinfold measurements on chest, abdomen and back, and measurements of the compressible soft tissue on the cheeks.

2. Mean values, medians, standard deviations, and range of variations are reported and discussed.

3. General trends of changes in the distribution of soft tissue masses during childhood as well as examples of individual deviations from these general trends are illustrated.

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APPLICATION OF THE GOMPERTZ CURVE TO THE OBSERVED PATTERN OF GROWTH IN LENGTH OF 48 INDIVIDUAL BOYS AND GIRLS DURING THE ADOLESCENT CYCLE OF GROWTH

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INTRODUCTION

THE longitudinal study of the physical growth of children from birth to maturity, which is being carried on by the Child Research Council, offers a fund of valuable data for the fitting of calculated growth curves to the observed pattern of growth of these boys and girls. The present paper deals with the 48 calculated curves which have been fitted to a portion of the observed pattern of growth in length of 48 boys and girls from the Child Research Council series.

The general pattern which is formed by the successive observed measurements of length, from birth to young adult life, of any one of these boys or girls is the pattern illustrated by fig. 1. During infancy and early childhood the pattern is a continually decelerating curve, which flattens out during the later childhood years to what is essentially a sloping straight line. Then, at a point somewhere near the time when the first outward sign of beginning secondary sex development is observed in the boy or girl, there is a sudden and dramatic change in the growth pattern. It now follows a course shaped somewhat like the letter *S*, with a sharp acceleration of the rate of growth for a time, followed in turn by a period of deceleration, and finally approaches a horizontal level as the adult length of the individual is attained.

Our separate treatment of the later *S*-shaped portion of the growth pattern, without attempting to find some mathematical equation which might be manipulated in such a way as to cover the entire growth period from birth to maturity, seems to us to need no apology. In the first place, the period from birth to maturity is itself only a portion of a larger growth pattern which has its beginning at conception of the individual, and which we can never know in its entirety. And in the second place, the *S*-shaped pattern of growth during the transition of the individual from a child to an adult is something so obviously new and different that it seems not only possible but desirable to treat it as a separate cycle of the growth process, which proceeds according to its own peculiar laws.

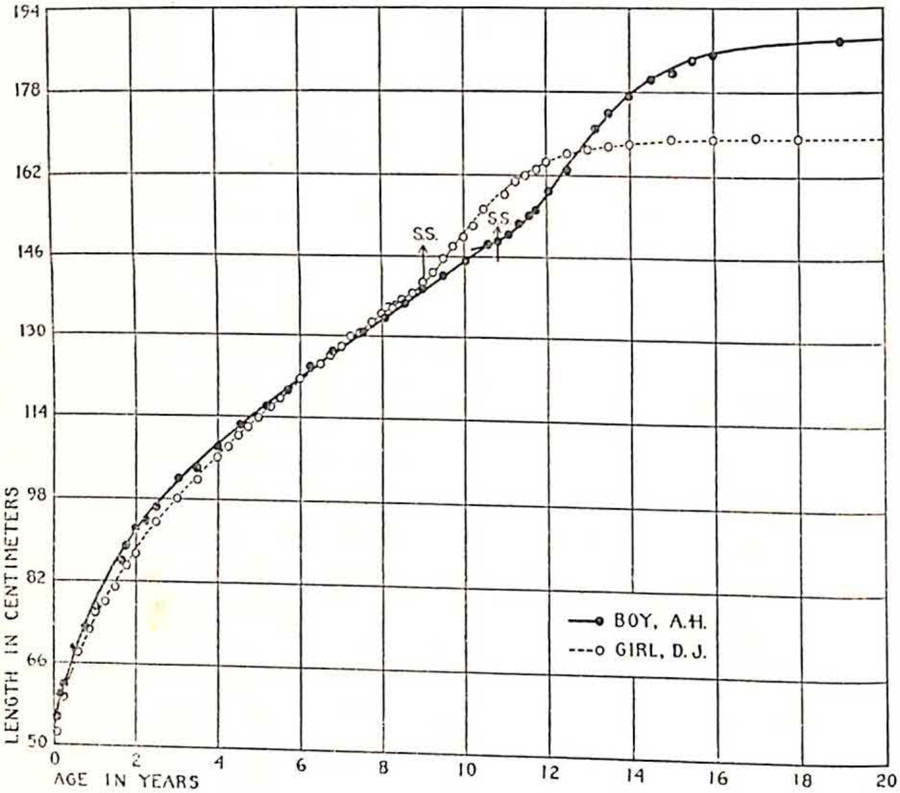


FIG. 1. GROWTH IN LENGTH OF AN INDIVIDUAL BOY AND AN INDIVIDUAL GIRL FROM BIRTH TO YOUNG ADULT LIFE.

Dots and rings are observed length measurements. Solid and broken lines are the calculated growth curves—equation of Jenss and Bayley for the early years, Gompertz equation for the *S*-shaped adolescent cycle.

SS marks first recorded sign of secondary sex development.

The concept of cycles of growth has been used by various authors in the field of growth, with somewhat varying definitions of its meaning. A practical definition from the standpoint of the pattern of human growth, as we see it, is the one proposed by Courtis ('37), who defines a cycle of growth as a period of specific maturation during which the elements and forces acting on the growth process are constant, within reasonable limits.

We are not in a position to discuss the hormonal stimuli that are acting, at different times, on the growth of the boys and girls used for this study, because hormone studies have not as yet been done on the boys and girls of the Child Research Council series. But it would be generally conceded that the hormonal stimuli affecting growth are not constant throughout the period from birth to maturity, and that there is a sudden entrance of new and different hormones into the picture at about the time when sexual maturing of the individual begins. We have therefore designated the *S*-shaped portion of the pattern of growth in length, which coincides approximately with the period of sexual maturing, as the "adolescent cycle" of growth in length. The term will be used with this meaning throughout the present paper.

For fitting the pattern of growth in length during infancy and childhood, we have made use, at the Child Research Council, of the growth equation of Jenss and Bayley ('37), which we hope to report in a paper at some later date. For the *S*-shaped adolescent cycle of growth, with which the present paper is concerned, we have used the equation of Benjamin Gompertz (1825), which was originally developed by Gompertz in 1825, in connection with actuarial life tables, and which was much later described as a growth curve applicable to the growth of biological organisms by Winsor ('32), by Courtis ('32), by Backman ('38), and by others.

Our choice of the Gompertz curve is based partly on the empirical finding that the *S*-shaped adolescent growth cycle of individual boys and girls could be fitted very satisfactorily with it; partly because the essential nature of the Gompertz equation (to be described in a later section of this paper) seems to us to be a logical one for describing the process of growth; and partly because the actual calculation involved in fitting the Gompertz curve seems much less laborious, at least when done with the help of the *isochron* table of Courtis ('32), than the calculation of other types of *S*-shaped exponential curves that might conceivably have been used in the same way.

Various types of exponential curves have been fitted satisfactorily by different workers to growth patterns in the form of a single *S*-shaped cycle. Robertson ('23), who believed that all growth is governed by a master chemical reaction, autocatalytic in nature, used the symmetrical logistic (autocatalytic) curve for the growth of certain animals and plants and also applied it to different cycles of human growth in weight (averages from mass data), getting a reasonably good fit for his adolescent cycle in man but apparently less good fits for other portions of the human growth pattern. Pearl ('25) and Pearl and Reed ('25) applied the symmetrical logistic curve to population growth and to certain types of animal and plant growth and also fitted the much more laborious and complicated skewed logistic curve to growth in weight of the rat, from the data of Donaldson, to growth of the pumpkin, from Robertson's data, and to growth in length of the tadpole's tail, from Durbin's data, obtaining very satisfactory fits with this curve. Merrell ('31) applied the symmetrical logistic curve satisfactorily to growth in weight of individual rabbits. Weymouth, McMillin, and Rich ('31) applied the Gompertz curve satisfactorily to growth in length of razor clams and also to Donaldson's data for growth of the rat in weight. Courtis ('32) gives many examples of satisfactory application of the Gompertz curve to growth of various plants and animals and also to mental growth in boys and girls and even to the learning of assigned lessons.

For fitting the observed pattern of the adolescent cycle of growth in length of boys and girls in the Child Research Council series, the Gompertz curve seems the most appropriate curve to use, though we make no argument for it as the only possible one that could describe the growth cycle correctly.

Our fitting of the 48 individual adolescent growth curves has increased our respect, not only for the Gompertz curve as a useful tool for describing growth in length during this age period, but also for the great superiority of longitudinal series of measurements of individuals, in contrast to the averaged measurements of a group of individuals. Fig. 4 is an illustration of the inadequacy of averaged annual measurements of a group of 24 girls as a description of the growth of individual girls from the same group, during the adolescent age period. The great variation in timing of the adolescent cycle, as well as in size at the start of the cycle and in the intensity of growth during the cycle, makes the pattern of the averaged measurements misleading and almost meaningless.

SUBJECTS

The subjects chosen for this study of the pattern of the adolescent growth cycle were 24 boys and 24 girls who had been followed from birth as part of a larger longitudinal study at the Child Research Council. They were selected from the larger group on the basis of being old enough, at the time when the curves were fitted, to have stopped growing in length, according to our measurements, and having a sufficiently complete series of measurements, over the period covered by the fitted curves, to give a clear picture of the pattern of their growth during that period.

The group of 48 boys and girls is a fairly homogeneous one. They are all white and born in the United States. Ancestral extractions, other than American, are from British and North European stock. No Jewish children are in this particular group, and none of Italian or Spanish extraction. Like the larger Child Research Council Series, the group is above average in socio-economic status.

The 48 boys and girls had been measured by anthropometer approximately once in three months, in most cases, until the early "teen" years then once every 6 months until the late "teens," and then once a year.

We fitted the calculated curves to the supine length of these individuals (always somewhat greater than standing height) because we hope to make, at a future date, some comparisons between the pattern of the adolescent growth cycle and the pattern of growth in infancy, when the children are necessarily measured supine. In cases where our older boys and girls had been measured only in the standing position, we corrected the measurement to the corresponding approximate supine length by the formula of Carrol Palmer ('32).

The plotted series of length measurements of each of the 48 boys and girls follows the general pattern of growth that is illustrated by fig. 1. Some, like the boy and girl shown in fig. 1, maintain their late childhood rate of growth consistently until the actual beginning of the *S*-shaped adolescent growth cycle. Others show a more or less noticeable falling off from their previous childhood rate during the last year or two before they get started on the adolescent cycle. In these latter cases, it would seem that the hormonal stimuli which had been responsible for the growth during infancy and childhood must have played out before the new stimuli that would initiate the adolescent growth cycle were ready to begin.

Once actually started on the adolescent growth cycle, the observed length of the 48 boys and girls conforms to the *S*-shaped pattern of the Gompertz curve with great uniformity and consistency. The boy and girl shown in fig. 1, the boy in fig. 2, the girl in fig. 3, and the 4 girls shown in fig. 4 are by no means exceptional in the close correspondence of their observed length to the pattern of the calculated Gompertz curves. It would seem that the urge for growth in length to proceed according to this pattern during adolescence is so strong that it would be difficult for anything to modify it significantly.

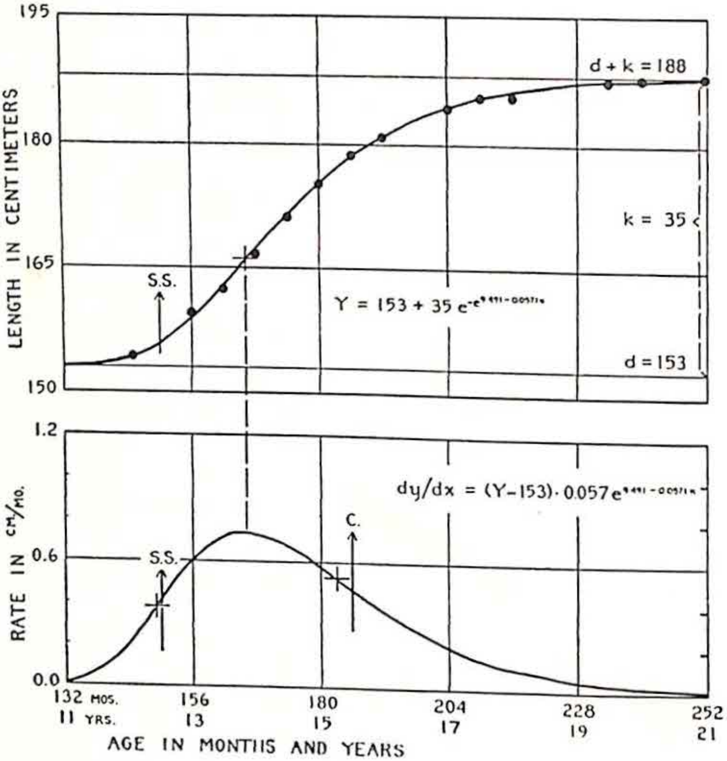


FIG. 2. CALCULATED GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE FOR ADOLESCENT CYCLE OF GROWTH IN LENGTH OF AN INDIVIDUAL BOY, W. S.

Dots are observed length measurements.

Crosses mark points of inflection. *SS* indicates first sign of secondary sex development. *C* indicates fusion of capitellum of humerus.

Most of the girls appear to get started on the adolescent growth cycle about 1½ to 2 years younger than the age when most of the boys get started on the cycle. By virtue of this earlier start, the girls soon become, for a time, considerably taller than the boys of corresponding age, only to be outstripped, however, by the boys later on. (See fig. 1.)

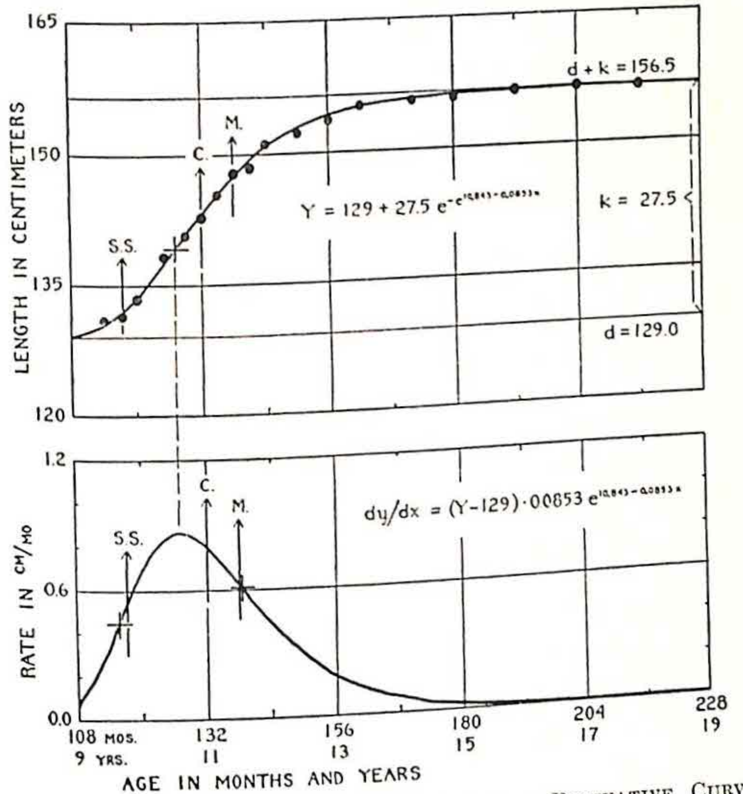


FIG. 3. CALCULATED GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE FOR ADOLESCENT CYCLE OF GROWTH IN LENGTH OF AN INDIVIDUAL GIRL, M. P.

Dots are observed length measurements.

Crosses mark points of inflection. *SS* indicates first sign of secondary sex development. *C* indicates fusion of capitellum of humerus. *M* indicates menarche.

In addition to the differences in timing of the adolescent cycle, we find individual differences and sex differences in the magnitude of the gain in length during the cycle and in the rate at which this gain is accomplished. But in all of these boys and girls the observed pattern of the adolescent cycle lends itself to being fitted satisfactorily by the Gompertz equation, now to be described in detail.

GENERAL DESCRIPTION OF THE GOMPERTZ CURVE

The simplest and most meaningful way of stating the Gompertz equation (though this is not the form that was used by Gompertz himself) is:

$$y = Ke^{-c^{a-bx}} \qquad (K,\ a, \text{ and } b \text{ being positive constants}). \qquad (1)$$

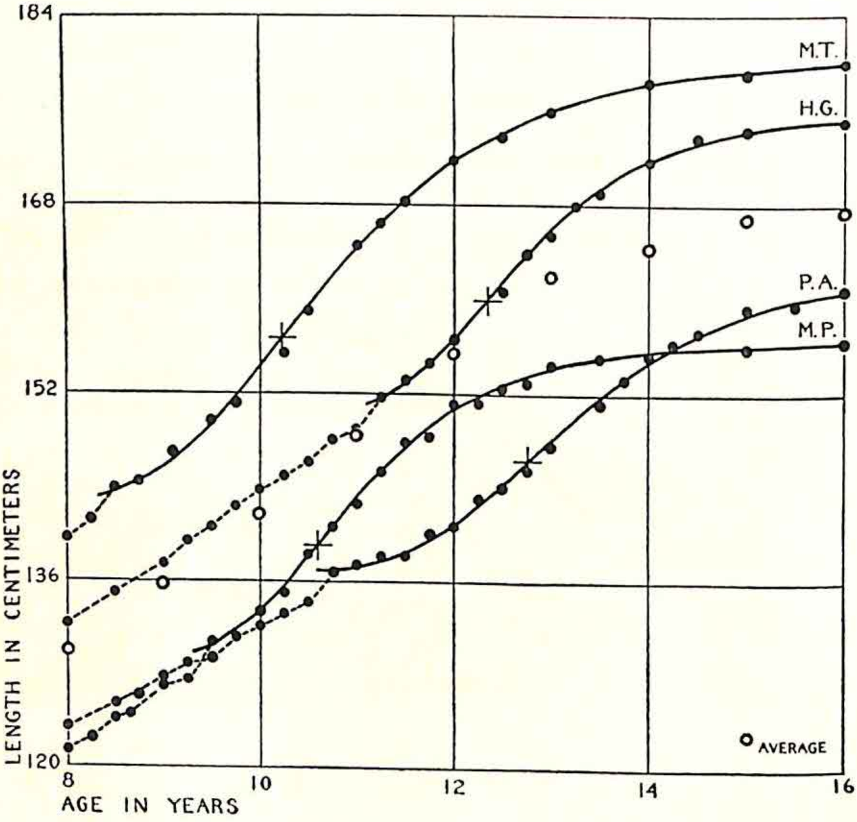


FIG. 4. AVERAGED ANNUAL LENGTH MEASUREMENTS (OPEN RINGS) OF 24 GIRLS FOR PERIOD FROM 8 TO 16 YEARS, COMPARED WITH OBSERVED MEASUREMENTS AND CALCULATED GOMPERTZ CURVES FOR 4 GIRLS OF SAME GROUP OF 24.

Note inadequacy of the averaged annual measurements as a description of individual growth during this age period.

Note also that the 16-year length of these girls could be predicted more accurately at 8 years than at 12 years.

The curve is a skewed S-shaped exponential curve with both a lower and an upper horizontal asymptote, the vertical distance between the asymptotes being represented by the constant K. With equation (1) the lower asymptote is $(y = 0)$ and the upper asymptote is $(y = K)$. In equal intervals of time, x, the proportion y/K increases to equal powers of itself.

At any point on the Gompertz curve:

$$\frac{y}{K} = e^{-e^{a-bx}} \tag{2}$$

and:

$$\log_e\left(-\log_e\left(\frac{y}{K}\right)\right) = a - bx. \tag{3}$$

The logarithmic equation (3) is a straight line, which can be calculated by the method of least squares if we know, or can estimate, the value of K. This straight line (3) has a negative slope $(-b)$ and a positive y-intercept (a). The x-intercept is $\frac{a}{b}$, the values of $(a - bx)$ being positive before that point and negative after it.

The absolute rate of growth, at any point on the Gompertz curve, is expressed by the first derivative. Differentiating, we have:

$$\frac{dy}{dx} = Ke^{-e^{a-bx}} \cdot be^{a-bx} \tag{4}$$

or, substituting from (1):

$$\frac{dy}{dx} = y \cdot be^{a-bx}. \tag{5}$$

The relative rate of growth decreases exponentially with increase of time:

$$dy\,/y = be^{a-bx}. \tag{6}$$

To Gompertz (1825), dealing with life tables, this property of the relative rate meant that man's power to avoid death is of such a nature that "in equal small intervals of time he loses equal proportions of his remaining power to resist destruction." Winsor ('32), considering the application of the Gompertz curve to the growth of biological organisms, suggests the paraphrase: "In equal small intervals of time the organism loses equal proportions of its power to grow."

By setting the second derivative of the Gompertz curve equal to zero, we find the abscissa of the point of inflection of the Gompertz curve. This point is also the point at which the first derivative reaches its maximum value.

Differentiating a second time, we have:

$$\frac{d^2y}{dx^2}=Ke^{-e^{a-bx}}\cdot b^2e^{a-bx}(e^{a-bx}-1). \tag{7}$$

Setting the factor $(e^{a-bx}-1)$ equal to zero, we have, for the point of inflection of the Gompertz curve (maximum point of first derivative curve):

$$\left\{\begin{aligned} e^{a-bx}&=1 && (8)\\ a-bx&=0 && (9)\\ x&=\frac{a}{b}. && (10)\end{aligned}\right.$$

and for the ordinate, from (1) and (8):

$$y=Ke^{-1} \qquad (=\text{approx. } 36.8\% \text{ of } K). \tag{11}$$

and for the maximum rate of growth, from (5) and (8):

$$\frac{dy}{dx}=bKe^{-1}. \tag{12}$$

The curve of the first derivative of the Gompertz curve is similar in general appearance to a logarithmic normal curve. Starting (approximately) from a lower limit of zero, the rate rises steeply, reaching its maximum at the point corresponding to the point of inflection of the S-shaped Gompertz curve. It then declines more gradually and finally approaches zero again as a limit as the Gompertz curve approaches its own upper asymptote. The derivative curve has two points of inflection, one before the maximum point and one after the maximum point. They are equally distant in time from the maximum point, as is shown by (16) and (19) below; but the second point of inflection is at a higher vertical level than the first point of inflection, as is shown by (18) and (21) below. The abscissas of the two points of inflection are found by setting the third derivative equal to zero.

Differentiating a third time, we have:

$$\frac{d^3y}{dx^3}=Ke^{-e^{a-bx}}\cdot b^3e^{a-bx}(e^{2(a-bx)}-3e^{a-bx}+1). \tag{13}$$

The factor $(e^{2(a-bx)}-3e^{a-bx}+1)$ is a quadratic expression in e^{a-bx}. Setting it equal to zero, we have:

$$\left\{\begin{aligned} e^{a-bx}&=\frac{3\pm\sqrt{5}}{2}=\left\{\begin{matrix}2.61803\\ \text{or}\\ 0.38197\end{matrix}\right. && (14)\\ a-bx&=\pm 0.9625. && (15)\end{aligned}\right.$$

Solving for the first point of inflection:

from (15): $$x=\frac{a}{b}-\frac{1}{b}(0.9625) \tag{16}$$

from (1) and (14): $$y=Ke^{-2.61803}\ (=\text{approx. } 0.073\,K) \tag{17}$$

from (5) and (14): $$\frac{dy}{dx}=2.61803\,bKe^{-2.61803}\ (=\text{approx. } 0.191\,bK). \tag{18}$$

Solving for the second point of inflection:

from (15): $$x=\frac{a}{b}+\frac{1}{b}\ (0.9625) \tag{19}$$

from (1) and (14): $$y=Ke^{-0.38197}\ (=\text{approx. } 0.683\,K) \tag{20}$$

from (5) and (14): $$\frac{dy}{dx}=0.38197\,bKe^{-0.38197}\ (=\text{approx. } 0.261\,bK). \tag{21}$$

APPLICATION OF THE GOMPERTZ CURVE TO THE ADOLESCENT CYCLE OF HUMAN GROWTH

Equation (1) describes an observed pattern of growth only when the observed pattern appears to be an *S*-shaped cycle starting approximately from zero level, as is the case for some forms of animal and plant life.

For the more complex pattern of human growth (fig. 1) we have seen that this is not the case. The *S*-shaped pattern, to which the Gompertz curve is applicable, does not begin at the zero level for actual length of the individual, but appears to start abruptly as a new cycle after a considerable portion of the total growth has already been completed. Therefore, in fitting the Gompertz curve to the observed adolescent growth cycle of a human individual, we cannot use for the actual length of the individual (starting from zero length) the same symbol that we use for the ordinate of the Gompertz curve itself (starting from the lower asymptote of the curve). In order to state the Gompertz equation in terms of the length of the growing individual, we take the symbol Y to denote the actual length of the individual, at any point, and we retain the symbol y for the ordinate of the Gompertz curve itself, at any point. It then becomes necessary to add to the equation another positive constant, d, to represent the level of the lower asymptote of the Gompertz curve. This gives us the equation that was used for calculating the curves reported in the present paper:

$$Y = d + y = d + Ke^{-e^{a-bx}}. \tag{22}$$

When equation (22) is applied to the observed adolescent growth cycle of individual boys and girls, the age of the individual, at any point, is represented by x, with $(x = 0)$ at birth. The actual length of the individual, at any point, is represented by Y. The ordinate, y, of the Gompertz curve is equal to $Y - d$, and represents the length that has been gained, at any point, by the individual after starting on his adolescent cycle of growth. The lower asymptote of the Gompertz curve, representing the length that had already been attained by the boy or girl before the start of the adolescent growth cycle, is $(Y = d)$. The upper asymptote, representing the adult length of the individual, is $(Y = d + K)$. The constant K represents the individual's total gain in length during the adolescent growth cycle. The constant b represents the rate at which the proportion y/K is increasing to equal powers of itself. This constant may be thought of as the individual's constant inherent rate of maturation through the S-shaped adolescent growth cycle. The constant a is merely the intercept at $(x = 0)$ of the logarithmic straight line (3). The proportion a/b, which is the abscissa of the point of inflection of the Gompertz curve, represents the age of the boy or girl at the point of inflection, which is also the point of maximum rate of growth of the individual. The product bKe^{-1} represents the maximum rate of growth attained.

The derivatives of the Gompertz curve remain the same, whether we state the original equation in the form of (1) or in the form of (22). We may use the symbol dy/dx or the symbol dY/dx interchangeably, since the additional constant, d, in equation (22) does not change the value of the derivative. However, the symbol y must be retained in those derivative equations which contain it, namely (5) and (6). And it must be remembered that, with equation (22), the symbol y denotes not the actual length of the growing individual but the length he has gained, at any point, after starting on his adolescent growth cycle.

A Gompertz curve and first derivative curve fitted to the observed adolescent growth cycle of an individual boy and an individual girl, respectively, can be seen in figs. 2 and 3.

The actual calculation of the curves reported in the present paper was done by means of the *Courtis table of isochrons.* This table is very helpful for fitting the Gompertz curve to observed data, because it converts the observed values of the percentage $100\,y/K$ directly to linear $\log_e(-\log_e)$ units called *isochrons,* thus doing away with the necessity of looking up natural logs twice over for every observed point used in the calculation of the curve.

The relation of the Courtis *isochron* to the Gompertz curve as described by equations (1), (2), and (3) can be explained as follows:

The Courtis *isochron* is 1/10 of the Courtis *T-unit.* The *T-unit* is defined, in effect, by Courtis ('32) as the time required for the proportion y/K at the point of inflection of the Gompertz curve to increase to its own power of itself. The number of *T-units* corresponding to the proportion y/K, at any point on the Gompertz curve, is represented by the symbol T, with $(T=0)$ at the point of inflection.

At the point of inflection of the Gompertz curve:

$$\left\{\begin{array}{ll} \text{by definition:} & T=0 \\ \text{from (11):} & \dfrac{y}{K}=e^{-1} \\ & \log_e\left(-\log_e\left(\dfrac{y}{K}\right)\right)=0 \\ \text{from (3) or (9):} & a-bx=0 \\ & x=\dfrac{a}{b}. \end{array}\right.$$

At the point where the proportion y/K at the point of inflection has increased to its own power of itself:

$$\left\{\begin{array}{ll} \text{by definition:} & T=1 \\ \text{by increasing to its own power of itself:} & \dfrac{y}{K}=(e^{-1})^{e^{-1}}=e^{-e^{-1}} \\ & \log_e\left(-\log_e\left(\dfrac{y}{K}\right)\right)=-1 \\ \text{from (3):} & a-bx=-1 \\ & x=\dfrac{a}{b}+\dfrac{1}{b}. \end{array}\right.$$

Thus we see that 1 *T-unit* is $(a/b+1/b-a/b)$ x-units $=1/b$ x-units.

In order to find the number of *T-units* corresponding to any number of x-units, we divide the number of x-units by $1/b$. Since $T = 0$ when $x = a/b$, the relation between T and x is:

$$T = \frac{x - \frac{a}{b}}{\frac{1}{b}} = -a + bx. \tag{23}$$

It is obvious that equation (23) is a straight line, and that this straight line is the mirror image, about ($x = a/b$), of the logarithmic straight line (3).

Since the Gompretz curve is asymptotic, it follows that the proportion y/K can never actually be zero, except at minus infinity, and can never actually be 1, except at plus infinity. For practical purposes, an arbitrary "zero time" is taken by Courtis ('32) at the point where $T = -3$, at which point he states that the percentage $100\,y/K$ is 0.000000189%. (At this point, from (23): $x = a/b - 3/b$.) Likewise, for the approximate time of "maturity" or completion of the growth cycle, Courtis ('32) takes the point where $T = 7$, at which point he states that the percentage $100\,y/K$ is 99.90917%. (At this point, from (23): $x = a/b + 7/b$.) The total duration of the S-shaped growth cycle is covered, for practical purposes, by 10 *T-units*.

In order to have a unit of convenient magnitude for calculations, Courtis ('32) takes the *isochron* as 1/10 of the *T-unit*, *i.e.*, as 1/10 of the time required for the proportion y/K at the point of inflection of the Gompertz curve to increase to its own power of itself, and as 1/100 of the approximate total duration of the S-shaped growth cycle represented by the Gompertz curve. The number of *isochrons* corresponding to the percentage $100\,y/K$, at any point on the Gompertz curve, is represented by the symbol I. Courtis ('32) takes the zero value of I at "zero time"—*i.e.*, $I = 0$ when $T = -3$.

Then, by definition:

$$I = 10(T + 3) \tag{24}$$

and, substituting from (23):

$$I = 10(-a + bx + 3) = 30 - 10a + 10bx. \tag{25}$$

Courtis ('32) writes this *isochronic* straight line in the form:

$$I = i + Rx \tag{26}$$

where, evidently:

$$i = 30 - 10a \tag{27}$$

and:

$$R = 10b. \tag{28}$$

All meaningful values of I are positive. But when, as is the case with the adolescent growth curve, the "zero time" for the start of the S-shaped growth cycle is a later time than $(x = 0)$, the projected intercept, i, at $(x = 0)$ will be negative.

Some equivalents that may be helpful are:

from (25):
$$a - bx = (30 - I)/10 \tag{29}$$

from (3) and (29):
$$\log_e\left(-\log_e\left(\frac{y}{K}\right)\right) = (30 - I)/10 \tag{30}$$

from (27):
$$a = (30 - i)/10 \tag{31}$$

from (28):
$$b = R/10 \tag{32}$$

from (31) and (32):
$$\frac{a}{b} = \frac{30 - i}{R}. \tag{33}$$

METHOD OF FITTING THE CURVE

As the first step in fitting the Gompertz curve to the observed growth of each of the 48 adolescents, we plotted the longitudinal series of length measurements of the boy or girl on a graph similar to fig. 1, with the length in cm represented by Y, and the age in months represented by x, with $(x = 0)$ at birth. Suitable levels for the upper and lower asymptotes of the S-shaped adolescent growth curve were then located by inspection from the pattern of the plotted points. The upper asymptote $(Y = d + K)$ was not difficult, because these boys and girls had stopped growing in length, according to our measurements, before the curves were fitted. We merely used the apparent "ceiling" to the nearest half cm as the approximate upper asymptote of the curve. The lower asymptote $(Y = d)$ was not always so easily located. In some cases, as for the boy in fig. 1, the take-off of the S-shaped growth cycle seemed very obvious, and there was no difficulty in estimating a suitable level for the lower asymptote. In other cases, as for the girl in fig. 1, the beginning of the S-shaped cycle was not so well defined. In such a case it was sometimes necessary to try several different estimates for the level of the lower asymptote and select the one which gave the best fit.

Having decided on the levels for the asymptotes, we could determine, for any point, the Gompertz curve ordinate $(y = Y - d)$, and we had our value for the constant K, which is the vertical distance between the asymptotes. We then selected 10 or 12 of the plotted observed points along the course of the S-shaped growth cycle, to be used for calculating the curve. We did not use, for the calculation, points lying close to either of the asymptotes, because a small error in an observed point near the asymptote involves a disproportionately large error in the corresponding log, and can cause undue distortion of the calculated straight line. Also, if one observed point appeared to deviate markedly from the general trend of the points, we would omit that particular point from the calculation.

For each of the selected observed points we calculated the percentage $100y/K$ and then obtained from the Courtis table the corresponding *isochron* value, I. The series of values of I, when plotted against corresponding values of x, lie approximately in a straight line, if suitable levels for the asymptotes of the curve have been chosen. If these values of I do not appear to make a straight line, it is an indication that a different asymptote should be tried. The *isochronic* straight line (26), $I = i + Rx$, was fitted through the series of values of I by means of the method of least squares. The calculated constants, i and R, were then converted by (31) and (32) to equivalent constants, a and b, for stating the Gompertz curve in its exponential form.

In order to draw the S-shaped exponential curve, we calculated the *isochron* value, I, for as many points as seemed desirable for drawing a good curve, and then converted each calculated I to the corresponding percentage $100y/K$ by means of the Courtis table. With this percentage known, it was easy to obtain first y, and then Y $(= y + d)$, for each of the calculated points. The curve was then drawn through the calculated (x, Y) points with the help of a curved ruler. Points for drawing the first derivative curve were obtained by substituting in equation (5) our calculated values of y, b, and $(a - bx)$. The abscissa and ordinate of the point of inflection of the Gompertz curve were determined by substituting in (10) and (11), respectively. The two points of inflection of the first derivative curve were located by substituting in (16) and (18) and in (19) and (21). The maximum point of the first derivative curve was located by substituting in (10) and (12).

For those who may be interested, a complete sample calculation of a Gompertz curve and its first derivative cure is appended at the end of this paper together with a calculation of points.

DISCUSSION OF FINDINGS

The various constants, asymptotes, and points of inflection of the 48 calculated Gompertz curves and first derivative curves give us a useful means of studying the typical pattern of growth in length during the adolescent growth cycle and the relation of certain physiological events to the pattern of the growth cycle. (See figs. 2 and 3.) They also give us a means of comparing or ranking individual boys or girls with respect to certain aspects of their pattern of growth, and a means of investigating sex differences in growth during the adolescent cycle.

Mean values and standard deviations for the constants, asymptotes, and points of inflection are listed in table 1. For all of these constants and landmarks of the fitted curves we find a considerable range of individual variation among the 24 boys and among the 24 girls of our group, and also some overlapping of the two sexes. However, as can be seen in table 3, we find strikingly significant sex differences, both with respect to magnitude of the constants and asymptotes and with respect to timing of the points of inflection of the curves.

Sex differences with respect to magnitude of the constants and asymptotes.

The lower asymptote ($Y = d$), which corresponds to the length already attained by the boy or girl at the time of starting on the S-shaped adolescent growth cycle, shows a significant 9 cm difference between the girls' mean of 141 cm and the boys' mean of 150 cm. This tendency for the girls to be shorter at start of the adolescent cycle is not surprising, because they tend also to be significantly younger than the boys, by about 1½ to 2 years, at the time of starting on the new cycle. (See fig. 1.)

The upper asymptote ($Y = d + K$), which corresponds to the adult length of the individual, shows a still greater difference between the girls' mean of 169 cm and the boys' mean of 183½ cm.

The constant K, representing the total gain in length during the adolescent growth cycle, shows a significant 5.3 cm difference between the girls' mean gain of 28.1 cm and the boys' mean gain of 33.4 cm. The typical larger gain of the boy is illustrated by fig. 1 and by a

TABLE 1

Constants, asymptotes, and points of inflection of the Gompertz curve for adolescent cycle of growth in length and its first derivative curve—24 girls and 24 boys

	MEAN FOR 24 GIRLS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	MEAN FOR 24 BOYS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Lower asymptote ($Y = d$) in cm (Length at start of the adolescent growth cycle)	140.8125	5.5205	± 1.15110	149.9375	4.44952	± 0.927789
Upper asymptote ($Y = d + K$) in cm (Adult length)	168.908	5.71354	± 1.19136	183.350	5.13907	± 1.07157
Constant K in cm (Length gained during the adolescent growth cycle)	28.0875	3.91938	± 0.817247	33.4125	3.43631	± 0.716520
Proportion of adult length contributed by K	16.6167%	2.23277%	± 0.465565%	18.2167%	1.70568%	± 0.355659%
Rate-constant b(T-units/mo.)	0.0736208	0.00781303	± 0.00162913	0.0654625	0.00520711	± 0.00108576
Growth pattern index ($100\ b/K$)	0.268792	0.0549772	± 0.0114635	0.198875	0.0314275	± 0.00655309
Constant a (Intercept of logarithmic straight line)	10.0855	1.35471	± 0.282478	10.5492	0.960281	± 0.200267
Age in mos. at point of inflection of Gompertz curve ($x = a/b$) (Rate is max.)	136.956	11.3295	± 2.36238	161.295	10.4238	± 2.17353
Age in mos. at 1st point of inflection of 1st derivative ($x = a/b - 1/b\ (0.9625)$)	123.734	11.5071	± 2.39940	146.5004	10.2837	± 2.14431
Age in mos. at 2nd point of inflection of 1st derivative ($x = a/b + 1/b\ (0.9625)$)	150.1725	11.3249	± 2.36141	176.0964	10.6785	± 2.22664
Interval in mos. between max. point and 1st or 2nd point of inflection of 1st derivative ($= \pm 1/b\ (0.9625)$)	± 13.2208	1.38062	± 0.287879	± 14.7950	1.16886	± 0.243724
Maximum rate of growth in cm/mo. ($dy/dx = bKe^{-1}$)	0.755833	0.098087	± 0.0204525	0.801375	0.0711388	± 0.0148335

TABLE 2

Timing of some physiological events in relation to the Gompertz curve for the adolescent cycle of growth in length—24 girls and 24 boys

	MEAN FOR 24 GIRLS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	MEAN FOR 24 BOYS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Age in mos. for 1st observed point on the Gompertz curve	119.750	11.8717	± 2.47542	140.1250	9.90023	± 2.07060
Age in mos. for 1st obs. of secondary sex development	121.625	12.4593	± 2.59796	142.1667	10.3463	± 2.15735
No. of mos. by which 1st obs. of secondary sex development precedes (—) or follows (+) 1st observed point on curve	+ 2.00000	7.33144	± 1.52871	+ 1.87500	10.0553	± 2.09667
No. of mos. by which 1st obs. of secondary sex development precedes (—) or follows (+) 1st point of inflection of the 1st derivative curve	— 2.10917	7.91943	± 1.65131	— 4.33375	10.0004	± 2.08523
No. of mos, by which 1st obs. of secondary sex development precedes point of inflection of the Gompertz curve	— 15.3333	7.82532	± 1.63169	— 19.5875	9.34943	± 1.94949
Age in mos. when X-ray shows fusion of the capitellum of the humerus ($N = 18$ ♀, 20 ♂)	142.389	9.49183	± 2.30210	180.9000	10.0891	± 2.31460
No. of mos. by which fusion of capitellum follows after point of inflection of the Gompertz curve ($N = 18$ ♀, 20 ♂)	+ 7.27778	4.21930	± 1.02333	+ 17.6400	5.35079	± 1.22756
No. of mos. by which fusion of capitellum precedes (—) or follows (+) 2nd point of inflection of the 1st derivative curve ($N = 18$ ♀, 20 ♂)	— 6.23556	4.29596	± 1.04192	+ 2.92950	5.38295	± 1.23493
Age in mos. at the menarche	151.625	12.3003	± 2.56479			
No. of mos. by which menarche follows after point of inflection of the Gompertz curve	+ 14.6625	4.41209	± 0.919985			
No. of mos. by which menarche precedes (—) or follows (+) 2nd point of inflection of the 1st derivative curve	+ 1.44167	4.44399	± 0.926636			

TABLE 3

Significant sex differences associated with the Gompertz curve for adolescent cycle of growth in length and its first derivative—48 adolescents

	MEANS FOR 24 GIRLS	MEANS FOR 24 BOYS	DIFFERENCE BETWEEN MEANS	SIGNIFICANCE	
				t	P
Lower asymptote ($Y = d$) in cm (Length at start of cycle)	140.8125	149.9375	9.1250	6.172	< 0.001
Upper asymptote ($Y = d + K$) in cm (Adult length)	168.908	183.350	14.442	9.013	< 0.001
Constant K in cm (Length gained during adolescent cycle)	28.0875	33.4125	5.3250	4.899	< 0.001
Rate-constant b in T-units per month	0.0736208	0.0654625	0.0081583	4.167	< 0.001
Growth pattern index $100\ b/K$	0.268792	0.198875	0.069917	5.295	< 0.001
Age in mos. at point of inflection of Gompertz curve ($x = a/b$)	136.956	161.295	24.339	7.581	< 0.001
Age in mos. at 1st point of inflection of 1st derivative curve	123.734	146.500	22.766	7.075	< 0.001
Age in mos. at 2nd point of inflection of 1st derivative curve	150.1725	176.0904	25.9179	7.985	< 0.001
Interval in mos. between point of maximum rate and 1st or 2nd point of inflection of derivative ($= \pm 1/b\ (0.9625)$)	$\pm$13.2208	$\pm$14.7950	1.5742	4.173	< 0.001
Age in mos. for 1st obs. point on Gompertz curve	119.750	140.1250	20.375	6.313	< 0.001
Age in mos. for 1st obs. of secondary sex devel.	121.625	142.167	20.542	6.083	< 0.001
Age in mos. when X-ray shows fusion of capitellum of humerus	142.389 ($N = 18$)	180.900 ($N = 20$)	38.511	11.759	< 0.001
Interval in mos. from point of inflection of Gompertz curve to fusion capitellum of humerus	7.2778 ($N = 18$)	17.6400 ($N = 20$)	10.3622	6.534	< 0.001

comparison of the girl's curve shown in fig. 3 and the boy's curve shown in fig. 2. Not only does the actual magnitude of K tend to be greater for the boys than for the girls, but there is also a significant tendency for the proportion of total adult length that is contributed by K to be somewhat greater in the boys. The mean value of this proportion is 16.6% of adult length for our girls, and 18.2% for our boys. By t-test for significance of difference $t = 2.731$; P is approximately 0.008.

The rate-constant b also shows a significant sex difference. This constant represents the rate (Courtis *T-units* per month) at which the proportion y/K is increasing to equal powers of itself. It is the individual's constant inherent rate of progress toward completion of the S-shaped growth cycle. The total range of individual variation for this constant looks small. But within this range there is a very significant difference in favor of a more rapid inherent rate of progress for the girls than for the boys.

Thus we find that the typical male pattern of growth during the adolescent cycle is characterized by a large total gain in length and a comparatively slow rate of progress in completing the cycle, while the typical female pattern is characterized by a smaller total gain in length and a more rapid rate of progress in completing the cycle.

A convenient index for describing the growth pattern of an individual, and for comparing or ranking individuals with respect to growth pattern, is the proportion b/K, which, like b and K, shows a significant sex difference, the smaller values of this index being typical for the boys and the greater values typical for the girls. In the form $100b/K$ the mean value of the growth pattern index is 0.269 for the girls and 0.199 for the boys. Only one boy has an index greater than the mean index for the girls; and only one girl has an index smaller than the mean for the boys.

There appears to be some relation, at least for the boys of our group, between the growth pattern index $100b/K$ and the general body build of the individual, particularly with reference to androgyny. A study of the nude photographs of these boys at 18 to 21 years reveals a preponderance of typically andric appearing boys among those having the smaller (more typically male) values of the index $100b/K$ and a preponderance of less andric appearing boys among those having the greater (less typically male) values of the index $100b/K$. Fig. 6 is an illustration of this. The two boys whose photographs are shown were selected because they impresed us as being the most andric (A) and the least andric (B) of the 24 boys of the group. Our evaluation of the androgyny status was based mainly on the criteria of Bayley and Bayer, as quoted by Shuttleworth ('49). In the photographs of (A) note the general leanness of body surface, with muscles and bony prominences clearly outlined beneath the skin; wide, muscular shoulder girdle; narrow hips; waistline inconspicuous and relatively low on the trunk; tight, muscular buttocks with deep concavities; lower extremities relatively long in proportion to total body height; thin, straight-sided thighs with an open

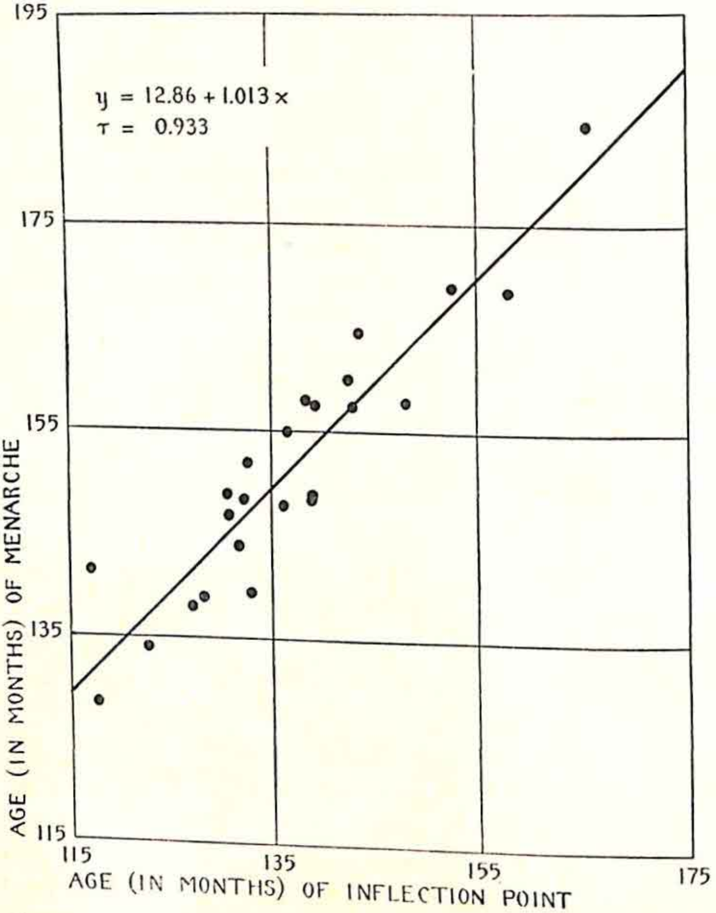


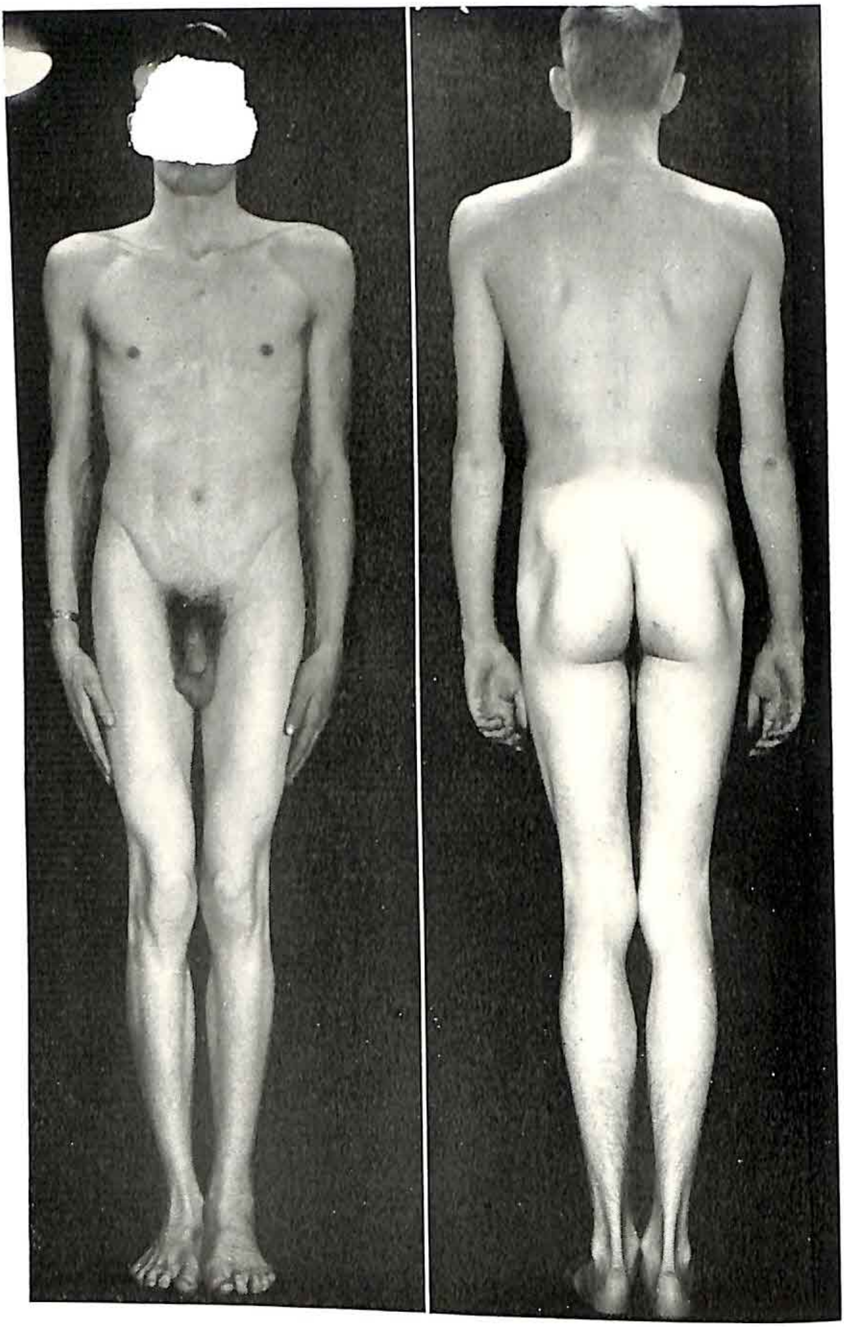
FIG. 5. ILLUSTRATION OF CLOSE CORRELATION OF AGE OF MENARCHE IN 24 GIRLS WITH AGE AT POINT OF MAXIMUM RATE OF GROWTH AS REPRESENTED BY POINT OF INFLECTION OF CALCULATED GOMPERTZ CURVE FOR GROWTH IN LENGTH OF THE SAME 24 GIRLS.

space between them; bulging calf muscles on inner side of leg. In the photographs of (B) note the general softness of body contours with muscles and bony prominences obscured by subcutaneous fat; hips wider in proportion to the shoulders; waistline more noticeable and relatively higher on the trunk; soft, cushion-like buttocks with very little concavity; lower extremities relatively short in proportion to total height; wide, funnel-shaped thighs with no space between them; less bulging of calf muscles on inner side of leg and greater curvature on outer side of leg. When the 24 boys of our group are ranked from the smallest to the greatest value of the growth pattern index $100b/K$, we find that (A) ranks 4th in smallness of this index (very typically male) and that (B) ranks 24th (least typically male), being also the only boy with an index greater than the mean index for girls of our group.

A study of the photographs of the girls of our group did not reveal any such striking example of correspondence between the growth pattern index and androgyny status. The relation, if any, would seem to be less clear-cut for the girls than for the boys.

Sex differences with respect to timing of the points of inflection of the curves.

The point of inflection of the S-shaped growth curves has been variously regarded as important or unimportant by different research workers in the field of growth. Extremes in attitude toward this point of maximum rate of growth are exemplified on the one hand by Weymouth, McMillin, and Rich ('31) and on the other hand by Brody ('27). Weymouth, McMillin, and Rich, who applied the Gompertz curve sucessfully to the growth in length of razor clams, as well as to Donaldson's data for growth of the rat in weight, believe that the point of inflection (point of maximum rate of growth) is of the nature of an artifact, with no biological significance, and that the curve of the relative rate—which decreases exponentially in a continuous smooth progression with no point of inflection—is much more significant than either the Gompertz curve itself or the curve of the absolute rate as represented by the first derivative. Brody, on the other hand, regards the point of inflection of the growth curves of both man and animals as a significant point for comparison of individuals or of species, and believes that this point is significantly related to puberty in both man and animals. Moreover, the findings of Shuttleworth ('39), with data from the Harvard Growth Study, and of Tanner ('51), with data from the

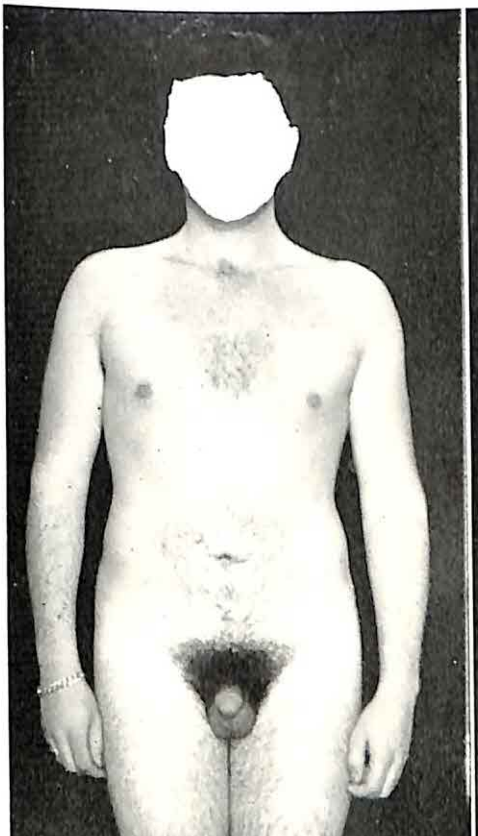


A

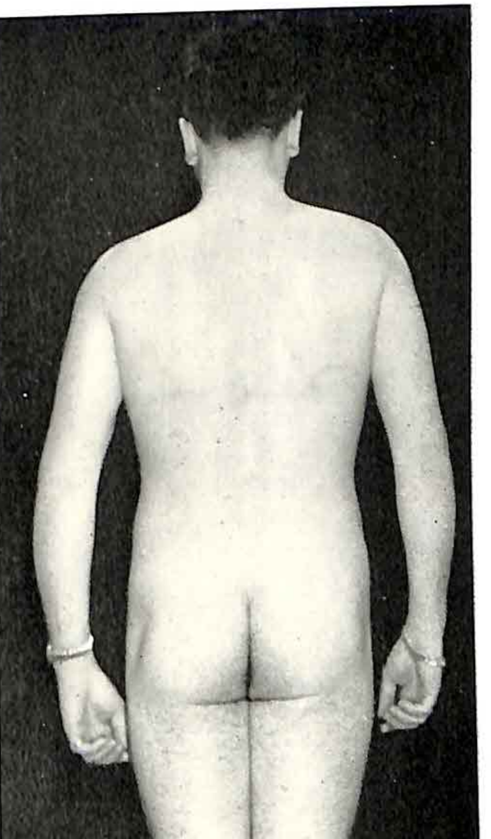
A

Fig. 6. Boy (A) with Typically Male Growth Pattern Index b/K and Boy (B) with Least Typically Male Index b/K. Compare Androgyny Status of the 2 Boys.

Anterior views are at 18–19 years, posterior views at 21 years.



B



B

Harpenden Growth Study, as well as the work of Simmons and Greulich ('43), with data from the Brush Foundation Series, and the earlier work of Boas ('32), with children from various New York schools, all point to a significant relationship between timing of the year of maximum increment in stature (which is at least closely related to timing of the point of inflection of the growth curve) and various other aspects of the individual's growth and development, including sexual maturation.

At the Child Research Council we find the point of inflection of the growth curve a meaningful and useful landmark, both for ranking boys or girls from the standpoint of early or late maturing and for investigating relations with other aspects of growth. Our group of 48 adolescents shows a significant sex difference of about two years between the girls' mean age at point of inflection of the Gompertz curve for growth in length and the boys' mean age at this point, the girls' mean age being not quite 137 months (11 yrs. 5 mos.) and the boys' mean being a little more than 161 months (13 yrs. 5 mos.). The mean ages for our boys and girls at this point of maximum absolute rate of growth are a year younger than the mean ages at "maximum growth" reported by Shuttleworth ('39) for 747 girls and 711 boys from the Harvard Growth Study. Shuttleworth, however, is not actually dealing with maximum rate of growth, as represented by the derivative at one particular point, but with the maximum increment achieved during an entire year. Since he takes his "age of maximum growth" at the end of the year of greatest gain, we should expect the point of inflection to be somewhere about the middle of that year and several months earlier than *MG*-age of Shuttleworth. Even allowing for this difference, however, the mean ages for our small group, at the point of maximum rate of growth, would appear to be somewhat younger than Shuttleworth's findings would lead us to expect.

We find significant sex differences, also, for age at each of the two points of inflection of the first derivative curve. As can be seen in table 3, the sex difference for the first point of inflection of the derivative curve is somewhat less than the difference for the point of maximum rate, and the difference for the second point of inflection is greater than the difference for the maximum point. This is a result of the sex difference, already mentioned, in the rate-constant *b*, which, as time goes on, makes for increasing advancement of the girl and increasing retardation of the boy, with respect to the proportion of the total adolescent growth cycle that has been completed at a given time.

We find still another significant sex difference in the time interval between the point of maximum rate and either of the two points of inflection of the derivative curve. This, too, is a result of the sex difference in the constant *b*, since the time interval is equal to $\pm 1/b$ (0.9625), as shown under the general description of the Gompertz curve and its derivative curve. The typical difference in shape of the derivative curves of the boy and the girl, which results from sex difference in the time interval between maximum point and inflection points, is strikingly illustrated by the wide derivative curve of the boy shown in fig. 2 and the much narrower derivative curve of the girl shown in fig. 3.

The maximum rate of growth itself, in cm per month, as represented by the derivative at the point of inflection of the Gompertz curve, does not show a significant sex difference for the 48 boys and girls of our group, though the boys' mean rate at the maximum point is slightly more rapid than that of the girls. This is due in part to the fact that the maximum rate depends on the product of the constants *b* and *K* ($dy/dx = bKe^{-1}$ at maximum point). This product neutralizes the sex differences for the individual constants, since *K* tends to be significantly greater for the boys while *b* tends to be significantly smaller for the boys.

The failure of our boys and girls to show a significant sex difference in maximum rate of growth attained might seem surprising in view of the findings of Shuttleworth ('39) and of Tanner ('51), in favor of a greater "peak velocity" of growth in height for boys than for girls. However, as has been pointed out, both Shuttleworth and Tanner were dealing with maximum increment for an entire year—not with velocity of growth, which is in a state of continual change from moment to moment throughout the year. Our boys do show a greater gain in length than our girls, for the adolescent cycle as a whole, as is shown by the sex difference in the value of the constant *K*. But the continually changing rate at which they are achieving that gain may or may not reach a higher point, at any time, than the maximum point that may be reached by a girl's rate. This, too, is illustrated by the boy's derivative curve in fig. 2 and the girl's derivative curve in fig. 3. This particular girl made a much smaller gain in length during her adolescent growth cycle than the gain made by the boy, but she attained, for a brief time, a more rapid rate of gain than was ever attained by the boy. Offsetting this, the boy, as is typical, maintained a rate of gain somewhere near his maximum rate over a considerably longer period of time than was possible for the girl, due to the girl's greater inherent urge toward rapid completion of the growth cycle, as represented by the constant *b*.

Timing of certain physiological events in the 48 adolescent boys and girls.

Means and standard deviations for timing of certain physiological events in these boys and girls, and for the relation of these events to the landmarks of the calculated growth curves, are listed in table 2. Here again, as would be expected, we find some significant sex differences, which are listed in table 3.

The age at which any boy or girl reached a length equivalent to the lower asymptote of the Gompertz curve and started on the new *S*-shaped growth cycle cannot be known exactly, because these boys and girls were measured not oftener than once in three months. A crude approximation, usually somewhat too high, is the age when the plotted observed length of the individual first appears to lie approximately on the *S*-shaped curve. (See the various locations of this first observed point on the curves shown in figs. 1 and 4.) Mean age for the first observed point on the adolescent curve is approximately 120 months (10 years) for the girls and 140 months (11 yrs. 8 mos.) for the boys, with a significant 20 months difference between the means.

Usually within a few months before or after the first observed point on the adolescent curve for growth in length we note the first recorded observation, by the pediatric examiner, of evidence of beginning secondary sex development in the boy or girl. Our records are by no means so accurate or complete, with respect to this finding, as we might wish, particularly for the older boys of our group. Individual examiners have varied both in their zeal for observing and recording the very earliest signs of secondary sex development and in their criteria for stating whether or not such development has started. At no time have the boys of the Child Research Council Series had actual measurements of size of the penis and testes, such as are reported by Tanner ('51) for the boys of the Harpenden Growth Study. Nor do we have "close-up" photographs of the genital region of the boys, such as are shown in the pictorial atlas of Shuttleworth ('49). The first secondary sex sign to be reported in our records has usually been, for the boys, the appearance of a few hairs at the base of the penis, and for the girls, the beginning of breast development. The timing of this first recorded observation is indicated by the letters *SS* on the growth curves shown in figs. 1, 2 and 3. Mean age at the *SS* point is between 121 and 122 months (10 yrs. 1 to 2 mos.) for the girls and approximately 142 months (11 yrs. 10 mos.) for the boys of our group. The interval, plus or minus, between the first observed point on the adolescent growth curve and the first recorded observation of secondary sex development shows a wide range of individual variation, especially for the boys; but the mean interval, for both sexes, is approximately two months after the first observed point on the growth curve. Nine of the 24 boys and 9 of the 24 girls had the first observation of secondary sex development before the first observed length point on the growth curve, while 15 had the first observation of secondary sex development later than, or synchronous with, the first observed length point on the growth curve.

In many cases we find the *SS* point very close to the first point of inflection of the derivative curve, as is illustrated by figs. 2 and 3. It may be either before or after the first point of inflection, the mean time for the *SS* point being about two months before the first point of inflection for the girls and about 4 months before the first point of inflection for the boys.

In all 48 boys and girls the *SS* point is several months before the point of maximum rate of growth in length, as represented by the point of inflection of the Gompertz curve. The mean time for the *SS* point is about 15 months before the point of maximum rate for the girls and about 19½ months before the point of maximum rate for the boys.

Another physiological event which is of interest in connection with the pattern of growth in length during the adolescent cycle is the fusion of the capitellum of the humerus. This is the first long-bone epiphysis to close, and in the absence of data for the complete skeletal age (which we do not have for the older boys and girls of the Child Research Council Series) it serves as a useful landmark of skeletal maturation. We know the time of fusion of the capitellum for 20 boys and 18 girls of our group of 48 adolescents, based on X-ray films taken every 6 months. We find a very striking sex difference, with no overlapping of the two sexes. Mean age of capitellum fusion is a little more than 142 months (11 yrs. 10 mos.) for the 18 girls and about 181 months (15 yrs. 1 mo.) for the 20 boys, with a significant difference of more than three years between the means. There is also an interesting sex difference in timing of fusion of the capitellum with relation to the growth curve. For both boys and girls we find the fusion occurring at some time after the point of maximum rate of growth, but the interval is significantly longer for the boys than for the girls. The girls' mean interval is about 7 months after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, while the mean interval for the boys is about 17½ months after the point of maximum rate of growth. It is interesting to note that the rate of growth in length has slowed down considerably, especially for the boys, before any long-bone epiphysis is closed, rather than being slowed as a result of closure of the epiphyses. In many of our boys we find that the timing of capitellum fusion is close to the second point of inflection of the derivative curve, as is illustrated by fig. 2, the mean interval for the 20 boys being not quite three months after the second point of inflection. In 14 boys the fusion follows after the second point of inflection, and in 6 boys it precedes this point. The girls, on the other hand, show fusion of the capitellum before the second point of inflection in all but two cases; and their mean interval for fusion is 6 months before the second point of inflection. The typical sex difference in timing of capitellum fusion with relation to the growth cycle is illustrated by figs. 2 and 3, where fusion is indicated by the letter *C*. The relation of fusion of the capitellum to the adolescent cycle of growth in length will be discussed further under correlations, in a subsequent section of this paper.

The timing of menarche in the girls of this group is, without exception, a number of months after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve. This is in general agreement with findings reported in the literature, for example by Simmons and Greulich ('43), for timing of menarche in relation to the year of maximum increment of standing height. The mean age of menarche for our 24 girls is 151.6 months (not quite 12 yrs. 8 mos.). The mean interval for menarche after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, is between 14 and 15 months. The girls of our group show a rather close correspondence between timing of menarche and the second point of inflection of the derivative curve. Twenty of the 24 girls ($83\frac{1}{3}\%$) have menarche within 6 months before or after the second point of inflection. Mean interval for the 24 girls is 1.4 months after the second point of inflection. The timing of menarche for the girl whose growth curve is shown in fig. 3 is indicated by the letter *M*. It will be noted that, as is typical, her rate of growth has slowed down very considerably from the maximum rate before the menarche occurs. The relation between menarche and the adolescent growth cycle will be discussed further under correlations.

Correlations.

Some correlation coefficients that are of interest in connection with the calculated Gompertz curves are listed in tables 4 and 5.

A. Correlations involving the constants and asymptotes of the curves (*table 4*): As would be expected, we find, for each sex, a significant positive correlation (0.756 for the 24 girls and 0.736 for the 24 boys) between adult length, as represented by the upper asymptote, $(d + K)$,

TABLE 4

Correlation coefficients involving the constants and asymptotes

	GIRLS		BOYS	
CORRELATION	r	95% Limits of confidence (z-transformation)	r	95% Limits of confidence (z-transformation)
$d(d + K)$	0.756	0.888 0.507	0.736	0.879 0.473
$d\ K$	—0.306	Not sig.	—0.193	Not sig.
$L_8(d + K)$	0.876	0.945 0.731	0.758	0.889 0.511
$L_{12}(d + K)$	0.736	0.879 0.473	———	———
$L_{14}(d + K)$	———	———	0.447	0.720 0.053
$K(d + K)$	0.391	Not sig.	0.542	0.776 0.177
$b(d + K)$	—0.133	Not sig.	—0.435	—0.713 —0.038
$b\ K$	—0.447	—0.720 —0.053	—0.553	—0.782 —0.193
$b/K\ BB$	0.157	Not sig.	0.500	0.752 0.121

Meaning of symbols used:

r = correlation coefficient.
d = length at start of adolescent growth cycle (lower asymptote of curve).
K = length gained during adolescent growth cycle.
L = length at specified ages, 8 years, 12 years, and 14 years.
b = rate-constant.
b/K = growth pattern index.
BB = body build index at 18 to 19 years.
Not. sig. = not significantly different from zero, by t-test for a sample of 24.

and length at the start of the adolescent growth cycle, as represented by the lower asymptote, d. This correlation is less striking than might perhaps be expected, due in part to the fact that some of the individuals who are taller at the start of the adolescent growth cycle are taller by virtue of starting the cycle at a later age and are therefore affected by the tendency, which we also find (see table 5) for the later maturing boys and girls to make a smaller gain in length during the adolescent cycle than the earlier maturing boys and girls. Even apart from differences in age at time of starting on the new cycle, we find that the individuals who have attained the greatest length before the start of the cycle are not necessarily the ones who achieve the greatest gain during the adolescent cycle itself. For neither the boys nor the girls of our group did we obtain a significant correlation between the adolescent gain, K, and length at time of starting on the adolescent cycle, as represented by the lower asymptote, d. Moreover, the small correlations which we did obtain are in a negative rather than a positive relation.

Our correlation between adult length $(d+K)$ and length at start of the adolescent cycle does not, of course, imply any specific age. For purposes of comparison we also calculated, for each sex, the correlation between adult length $(d+K)$ and the observed length of the same individuals at two specific ages—8 years and 12 years for the girls and 8 years and 14 years for the boys. The correlations with length at 8 years are somewhat better than our correlations with length at start of the adolescent cycle, as represented by d. In contrast to this, the correlation with length at 12 years for the girls and the correlation with length at 14 years for the boys are less good than either the correlation with length at 8 years or the correlation with length at start of the cycle, as represented by d. Fig. 4 is a good illustration of the temporary distortion of relative position of individuals in a group, which may be caused by differences in timing and intensity of growth during the adolescent cycle, and which would lead us to expect a better correlation between adult length and length of these girls at 8 years than we would expect between adult length and length of the same girls at 12 years. Our better correlations with length at 8 years than with length at 12 years and 14 years are in general agreement with reports in the literature on correlations between adult standing height and height at various specifc ages, for example by Shuttleworth ('39), with several hundred boys and girls from the Harvard Growth Study, and by Tuddenham and Snyder ('54), with 70 girls and 66 boys from the California Guidance Study.

For the relation between adult length $(d+K)$ and gain during the adolescent cycle, as represented by K, we find a weak but significant positive correlation (0.542) for the 24 boys, but only a suggestive positive correlation (0.391) for the girls. The better correlation for

TABLE 5

Correlation coefficients involving timing of point of maximum rate of growth

CORRELATION	GIRLS r	GIRLS 95% Limits of confidence (z-transformation)	BOYS r	BOYS 95% Limits of confidence (z-transformation)
a/b Max	—0.746	—0.884 —0.490	—0.603	—0.809 —0.264
a/b K	—0.725	—0.873 —0.455	—0.410	—0.705 —0.008
a/b b	0.031	Not sig.	—0.185	Not sig.
$a/b\,(d+K)$	—0.161	Not sig.	0.113	Not sig.
a/b L_8	—0.489	—0.745 —0.107	—0.331	Not sig.
a/b BB	—0.098	Not sig.	0.037	Not sig.
a/b SS	0.784	0.902 0.557	0.558	0.789 0.199
Pt SS	0.723	0.872 0.451	0.500	0.752 0.121
a/b Cap	0.925 ($N = 18$)	0.972 0.806	0.862 ($N = 20$)	0.944 0.678
a/b Men	0.933	0.971 0.849	——	——

Meaning of symbols used:

r = correlation coefficient.

a/b = age at point of maximum rate of growth (abscissa of point of inflection).

Max = maximum absolute rate of growth (dy/dx at point of inflection).

K = length gained during adolescent growth cycle.

b = rate-constant.

$(d + K)$ = adult length (upper asymptote of curve).

L_8 = observed length at 8 years.

BB = body build index at 18 to 19 years.

SS = age of first recorded observation of secondary sex development.

Pt = first observed point on S-shaped adolescent growth curve.

Cap = age when X-ray first shows fusion of capitellum of humerus.

Men = age of menarche in the girls.

Not sig. = not significantly different from zero, by t-test for a sample of 24.

the boys may be partly due to the fact that, as already noted under sex differences, the adolescent gain, K, contributes a greater proportion of the total adult length for the boys than it contributes for the girls.

Our correlation between adult length $(d + K)$ and the rate-constant b is in the negative direction and is even weaker than the correlation between adult length and the constant K, being of only borderline significance for the boys and not significant for the girls.

We find a weak but significant negative correlation between the constant K and the constant b, showing some tendency for a greater total gain in length during the adolescent cycle to be associated with a less rapid rate of progress in completing the cycle.

Since the photographs of our boys had shown some very suggestive evidence of a relationship between the growth pattern index $100b/K$ and the general body build, we wanted to try a correlation between this index and some sort of index that would be an expression of the body build. The boys and girls of the Child Research Council series have never been classified according to Sheldon's somatotypes, so we could not use the somatotype status for correlations. We did, however, use a composite index of body build, made up from indices which were available for the boys and girls of our group. This body build index consists of the product of relative sitting height and weight-height index, divided by the shoulder-width-hip-width index. High values for this composite index correspond to a relatively short-legged, relatively heavy, and wide-hipped person; in other words, a person with a generally gynic build. Low values of the index correspond to a relatively long-legged, lean, and broad-shouldered person; in other words, a person with a generally andric body build. The 48 adolescents of our group show a significant sex difference ($t = 4.754$; P is less than 0.001) in favor of smaller values of the body build index in the boys. The correlation which we obtained between this body build index and the growth pattern index $100b/K$ was significantly positive for the 24 boys, but disappointingly weak (0.500). For our girls the correlation between the two indices is not significant.

B. Correlations involving timing of point of maximum rate of growth (table 5): Some of the more interesting correlations which we investigated were those which involved the timing of the point of maximum rate of growth in these boys and girls, as represented by age at the point of inflection of the Gompertz curve ($x = a/b$).

For the relation between age at the point of maximum rate of growth in length and the maximum rate that is attained by the individual, we find a significant negative correlation (—0.746 for the 24 girls and —0.603 for the 24 boys) showing a tendency for those who reach their maximum rate of growth at an early age to attain a more rapid maximum rate than those who reach this point at a later age. This is in general agreement with reports in the literature by Shuttleworth ('39), by Tanner ('51), and by Simmons and Greulich ('43), with respect to greater "intensity of growth" or a greater "peak velocity" for those individuals whose adolescent spurt occurs early.

For the relation between age at the point of maximum rate of growth in length and the actual magnitude of the total adolescent gain in length, as represented by the constant K, we again find a significant negative correlation (—0.725) for the girls of our group; but for our boys this negative correlation is of only borderline significance.

For neither our boys nor our girls do we find any significant correlation for age at the point of maximum rate of growth and the value of the rate-constant b. Nor do we find any correlation between age at the point of maximum rate of growth and the adult length attained by the individual, the early maturing individuals (from this standpoint) showing no tendency to be either taller or shorter as adults than the later maturing individuals.

Reports in the literature had led us to expect a significant negative correlation between age at the point of maximum rate of growth and the observed length of the individual at the age of 8 years; in other words, that the children whose length at 8 years was greater would tend to reach their adolescent spurt at an earlier age. We did obtain negative correlations, but they are disappointingly weak (—0.489 for our 24 girls and —0.331, which is not significant, for our boys).

We also had some expectation of finding a significant correlation between age at the point of maximum growth and the individual's body build index, especially in view of the report of Tanner ('51), and the findings of other authors quoted by Tanner, to the effect that early maturing individuals tend to be less linear or ectomorphic, to have relatively shorter legs and wider hips, and to be generally less andric or more gynic than the later maturing individuals. However, for neither the girls nor the boys of our group do we find any correlation whatsoever between our body build index and age at the point of maximum rate of growth.

Our best correlations are those associated with timing of point of maximum rate of growth and timing of certain physiological events in these boys and girls. The correlation between age at point of maximum growth and age of the first recorded sign of secondary sex development is significantly positive (0.784 for the girls and 0.558 for the boys). The poorer correlation for the boys is, we believe, largely due to greater inaccuracy of our records of the *SS* age for the boys. Our correlations between first sign of secondary sex development and first observed length point on the adolescent growth curve are essentially the same as the correlations between point of maximum rate of growth and first sign of secondary sex development—again considerably better for our girls than for our boys.

Our correlations between age at point of maximum rate of growth and fusion of the capitellum of the humerus (the first long-bone epiphysis to close) are good for both the girls (0.925) and the boys (0.862).

Best of all is our correlation between age at point of maximum rate of growth and age of the girl at menarche (0.933). We would, of course, expect a significant correlation with menarcheal age, in view of the reports by Shuttleworth ('39), by Simmons and Greulich ('43), and by Tanner ('51). But we were delighted to find our own correlation as good as it is. It strengthens our faith in the validity of the calculated Gompertz curves as a description of the growth pattern of individual adolescents. (See fig. 5 for calculated regression line and observed age points for the relation between menarcheal age and age at point of maximum rate of growth, as represented by the point of inflection of the calculated Gompertz curve, for the 24 girls of our group.)

SUMMARY

The Gompertz equation $Y = d + Ke^{-e^{a-bx}}$ has been fitted to observed length during the adolescent growth cycle of 48 individual boys and girls.

The constants, asymptotes, and points of inflection of the calculated Gompertz curves give us useful tools for studying the typical pattern of growth during the adolescent cycle, for investigating individual differences and sex differences in pattern of growth, and for investigating the timing of certain physiological events in relation to the pattern of the growth cycle.

We find significant sex differences in the value of the constants K and b; in the level of the lower and upper asymptotes of the curve; in the timing of the point of maximum rate of growth, as represented by the derivative at the point of inflection of the Gompertz curve; in the timing of both points of inflection of the first derivative curve; in the timing of certain physiological events that appear to be related to the pattern of the growth cycle; and in the body build index of these individuals.

Within each sex we find significant correlations between several of the constants and asymptotes of the curve; between the timing of the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, and timing of physiological events such as the first sign of secondary sex development, the closure of the first long-bone epiphysis, and in girls the occurrence of the menarche; between timing of the point of maximum rate of growth and the maximum rate that is attained; and between timing of the point of maximum rate of growth and magnitude of the total gain in length during the adolescent cycle, as represented by the constant K.

We find no significant correlation between timing of the point of maximum rate of growth and the adult length attained by the individual and very little evidence of correlation between timing of the point of maximum rate of growth and length of the individual at age 8 years.

A comparison of nude photographs, at least of the boys of our group, with the growth pattern index $100b/K$ suggests a relationship between the value of this index and body build of the individual, particularly with reference to androgyny. But the actual correlation between the index $100b/K$ and our body build index for these boys at age 18 to 19 years is disappointingly weak.

We also find no correlation between our body build index and timing of the point of maximum rate of growth, though various reports in the literature led us to expect a more gynic body build in those individuals who reach their point of maximum rate of growth at an early age.

A comparison of our individual growth curves for the adolescent cycle of growth in length with the trend of the averaged annual measurements of the same group of individuals brings out the inadequacy of averaged measurements as a description of the growth of individuals during this age period.

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APPENDIX

SAMPLE CALCULATION OF GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE USING COURTIS TABLE

(This is the curve shown in fig. 3.)

Observed upper asymptote $(d + K) = 156.5$ cm
Estimated lower asymptote $d = 129$ cm
Constant K $156.5 - 129 = 27.5$ cm

x AGE (MOS.)	Y OBS. LENGTH (CM)	$y = Y - 129$ CM	PERCENT $100\, y/K$	I FROM COURTIS TABLE
117	131.2	2.2	8.00	20.73
120	133.4	4.4	16.00	23.94
123	135.0	6.0	21.82	25.79
125	138.3	9.3	33.81	29.18
129	140.6	11.6	42.18	31.48
135	145.4	16.4	59.64	36.60
138	147.9	18.9	68.73	39.81
144	151.2	22.2	80.73	45.42
150	152.5	23.5	85.45	48.50
162	155.1	26.1	94.91	59.52

Calculation of straight line, $I = i + Rx$, by method of least squares:

$N = 10$

$$m_x = \frac{\Sigma x}{N} = 134.3 \qquad m_I = \frac{\Sigma I}{N} = 36.097$$

$$\sigma_x = \sqrt{\frac{\Sigma x^2}{N} - (m_x)^2} = 13.6678 \qquad \sigma_I = \sqrt{\frac{\Sigma I^2}{N} - (m_I)^2} = 11.6737$$

Sum of cross products: $\Sigma xI = 50{,}071.30$

Correlation coefficient: $$r = \frac{\dfrac{\Sigma xI}{N} - m_x m_I}{\sigma_x \sigma_I} = \frac{159.3029}{159.5538} = 0.998427$$

Slope of calculated line: $R = r\dfrac{\sigma_I}{\sigma_x} = 0.852759$

Intercept: $i = m_I - Rm_x = -78.43$

Calculated straight line: $I = i + Rx = -78.43 + 0.852759x$

Equivalent constants for exponential form of Gompertz curve:

$$b = R/10 = 0.0852759$$

$$a = (30 - i)/10 = 10.843$$

CALCULATION OF POINTS

x AGE (mos.)	CALC. I^*	$100\, y/K$ (Courtis table)	CALC. y (cm)	CALC. $Y = y + 129$ (cm)	$(a - bx) = (30 - I)/10$	e^{a-bx} (Expon. table)	be^{a-bx} $(b = 0.0853)$	$dy/dx = ybe^{a-bx}$ (cm/mo.)
108	13.69	0.60	0.17	129.17	1.631	5.109	0.4358	0.074
114	18.81	4.69	1.29	130.29	1.119	3.065	0.2614	0.337
120	23.93	15.97	4.39	133.39	0.607	1.840	0.1570	0.689
126	29.05	33.30	9.16	138.16	0.095	1.100	0.0938	0.859
132	34.17	51.73	14.23	143.23	—0.417	0.659	0.0562	0.800
138	39.28	67.35	18.52	147.52	—0.928	0.395	0.0337	0.624
144	44.40	78.90	21.70	150.70	—1.440	0.237	0.0202	0.438
150	49.52	86.76	23.86	152.86	—1.952	0.142	0.0121	0.289
156	54.64	91.84	25.26	154.26	—2.464	0.085	0.0072	0.182
162	59.76	95.04	26.14	155.14	—2.976	0.051	0.0044	0.115
168	64.87	96.99	26.67	155.67	—3.487	0.030	0.0026	0.069
174	69.99	98.18	27.00	156.00	—3.999	0.018	0.0015	0.040
180	75.11	98.97	27.22	156.22	—4.511	0.011	0.0009	0.024
192	85.35	99.61	27.39	156.39	—5.535	0.0039	0.0003	0.008
204	95.58	99.86	27.46	156.46	—6.558	0.0015	0.0001	0.003
216	105.82	99.95	27.49	156.49	—7.582	0.0005	0.00004	0.001

Point of inflection of Gompertz curve

(Maximum point of first derivative curve):

$$x = a/b = 127.15 \text{ mos.}$$
$$y = 0.368K = 10.12 \text{ cm.}$$
$$Y = 129 + 10.12 = 139.12 \text{ cm.}$$
$$dy/dx = y \cdot b = 10.12(0.0853) = 0.863 \text{ cm/mo.}$$

First point of inflection of first derivative curve:

$$x = a/b - 1/b(0.9625) = 127.15 - 11.28 = 115.87 \text{ mos.}$$
$$dy/dx = 0.19bK = 0.446 \text{ cm/mo.}$$

Second point of inflection of first derivative curve:

$$x = a/b + 1/b(0.9625) = 127.15 + 11.28 = 138.43 \text{ mos.}$$
$$dy/dx = 0.26bK = 0.610 \text{ cm/mo.}$$

[*] The value of I, for each given value of x, is calculated from the straight line, $I = i + Rx$, by substituting the calculated values of the constants R and i.

BOOK REVIEWS

Dynamic Anthropometry. Edited by EARL W. COUNT. 203 pp. Ann. N. Y. Acad. Sci., *63*, Art. 4, 1955.

These 200 pages are the record of a two-day symposium held by the New York Academy of Sciences; they contain 16 papers of varying length and quality, attended by virtually no discussion. Most appropriately the book begins, more or less, with a charmingly oldfashioned photograph of D'Arcy Thompson and ends with a rather reflective picture entitled "close-up buttock pattern (seated)" which strongly suggests the quizzical expression of an ectoplasmic owl.

Professor Earl Count was in the chair at the symposium and he contributes an introduction which travels both wide and deep into the subject matter of human biology. I cannot honestly feel, however, that the conference as a whole has followed him, and perhaps this was due to some confusion of thought as to its purpose. One wonders to whom the proceedings are addressed; with 16 papers read in two days no contributor can hope to do more than sketch the outlines of his topic, and none of the treatments is at a level which would inform the hardened professional physical anthropologist. The best audience to recommend the book to would be that of the senior anthropology student, perhaps, particularly as the background for a seminar wherein the teacher could follow up some of the many hares started, but not pursued, in these pages.

The title, *Dynamic Anthropometry*, has a pleasantly ambiguous air: is it the men or the measurements that are in motion? After all, anthropometry itself is a craft, a mere collection of methods for measuring aspects of the human. A book, or a series such as *Methods in Medical Research*, preferably combined with tabulations of results similar to those in the *Handbook of Physiological Data*, would be extremely useful at the present juncture, provided only that the methods were described and illustrated in sufficient detail for anyone with proper training to repeat them. The methods would have to include the classical body measurements, the measurements used in kinematic anthropometry, body photography, still and moving, measurements by X-rays, measurements of skin and eye and hair color, measurements of body tissue composition by physical and chemical means, and such other physical and chemical procedures as are not readily available from other sources. Certain mathematical techniques peculiar to anthropometry or developed particularly in its service should also be included. But clearly this symposium does not aim at being a handbook of anthropometric methods. At first, it seems, it is the measurements that are on the move; latterly, after p. 553, the men.

This last third is in some ways the most interesting portion of the book, in that the techniques for dealing with the quantification of movement in man are perhaps less well known than they should be. Elftman contributes a short and pithy introduction to the study of man's movement. He mentions for example, though he does not have time to go into the really interesting problems: the type of build most suited anatomically to each type of athletic task, the effect of putting on fat on patterns of movement and the ways in which people of different body builds have their action patterns preconditioned by their shape. Dempster, in the next contribution, carries further the technical discussion of plotting movements, linkage systems, and joint ranges, and touches on the possibility of studying the effect of psychological states on habitual action patterns. We have the foundation here, perhaps, of a true investigation of postural symbolism and "language"; a study which would bring the human biologist and the psychologist into even closer contact as they endeavor to pin down between them the elusive concept of the body image and its changes. Evans, in the same section, writes on the stress-coat technique for predicting the likely sites of fracture of bones, Abt introduces a peculiarly life-like and useful full-size model of a man with correct joint linkages and properly distributed weight, and Hertzberg describes with skill and humor some problems encountered in human engineering, in particular that perennial war-time problem "What happens to the buttocks when you sit on them?" Gumbril's Patent Smallclothes appear at last in practical form on page 626—no longer, alas, the "delicious pneu" but only "dynamic inflatable cushion"—indeed, they appear with complications Huxley never envisaged, but would doubtless have dealt with effectively, seeing they consist of a continuous forty-second cycle of gluteal tumescence and detumescence. But then Gumbril never had to sit in chapel for 6-10 hours at a stretch, which is Dr. Herzberg's target time.

To return, however, to the first two-thirds of the book: here the designation "dynamic" is used, I suppose, figuratively, and in the hope that the subjects dealt with constitute the growing point of physical anthropology. Rashevsky considers plant and animal form from the point of view of engineering design; Brillouin contributes an intriguing note well calculated to secure readers for books and discussions on information and system theory as applied to living organisms; Mainland has some characteristically sensible things to say about elementary statistics; Bonin urges anthropologists to begin quantitative work on the structure of the brain. There are two papers that deal with the allometric technique of handling growth data; neither advances the subject much. Moss has the unenviable task of presenting in 8 pages data that he refers to as in the press in two complete papers. It may be this condensation which is responsible for his sweeping blandly without apparently noticing them, through all the difficulties of the allometric technique, pointed out in detail by Sholl ('54), Tanner ('51) and above all Richards and Kavanagh ('45). Dr. Richards himself contributes, at p. 490, the wisest remarks on allometry to be found here. He also contributes one of the best articles in the book; it covers, though, less thoroughly, the ground of the brilliant 1945 chapter in D'Arcy Thompson's Festschrift, and if it sends a few readers back to that fundamental paper, that is enough to justify the symposium.

Meredith contributes some very pertinent and experienced remarks about the technical precautions necessary for taking measurements suitable for use in longitudinal studies of individual children; Garn discusses the technique of so-called pattern analysis with great clarity and effectiveness—though not enough, I suspect, to convince biometricians of its usefulness when compared with more rigorous, if more exacting, multivariate techniques. Brožek has an excellent chapter on the study of body composition by physical, chemical and anthropometric techniques, in which he compares the uses of each type of approach, refreshingly refuses to be partisan, and argues for a combined attack on the problems of human shape, size and composition by means of simultaneously applied caliper measurements, X-ray measurements, somatotype pictures, and densitometric and chemical dilution methods—a program with which I am in total agreement.

Certainly this is a useful symposium at a workaday level. But *dynamic anthropometry?* Surely that must mean something more than this? Certainly new methods are mentioned, though scarcely paraded, here and some older and relatively neglected ones, like the method of transformed co-ordinates, are represented. But new techniques do not make anthropometry dynamic any more than the wide screen makes the cinema artistically fruitful. Only by the *use* of the measurements can anthropometry earn for itself the title of this volume; only by the significance of its contribution to the general biological context of the day. And in this respect it seems to me this book falls short of its title's promise. Where are the chapters describing the contributions of heredity and environment to the genesis of adult physique, the effect of culture and subculture on the total fat, the place of physique in assortative mating in Western and Eastern cultures, the statistics describing the selection of physique by climate recently investigated by Schreider? Where are the descriptions of the mathematical techniques needed to place the data of physical anthropology once more in the forefront of genetical theory, this time through polygenic systems like those controlling stature? Where are methods of comparing the total growth curves of man and apes, man and man; for describing the effects of sickness, the secular changes, the usefulness as a sociological yardstick? I am aware this is unfair criticism; indeed, no criticism at all, since I am asking for a different symposium and a different book. I do so unrepentantly; let us praise this one as useful in so far as it goes, but not think that it goes very far. Anthropometry is a technique; let us publish a series of detailed descriptions so as to catalog our working tools; and let us separately, one day of courage, publish an account of what uses, in theory and practice, these techniques can be put to, an account of what the growing discipline of human biology has to offer in the attempt to understand man as part of nature.

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Demographic Yearbook 1955. Statistical Office of the United Nations. xi + 781 pp. United Nations, New York, 1955. $8.50 Clothbound ($7.00 Paperbound).

Investigators in the various branches of the biological sciences will find this volume, the seventh in an annual series, a rich storehouse of information on international population data and vital statistics. In addition to bringing up-to-date the usual time series on population estimates, fertility, mortality, longevity, marriage and divorce, each issue of the *Demographic Yearbook* features a special topic of demographic interest. A large part of this edition is given to the population censuses taken in a large number of countries throughout the world in the decade 1945-1954, and constitutes the most comprehensive compilation of census returns ever assembled.

Recent census data for the individual countries are given in considerable detail—according to age, sex, marital status, urban-rural distribution, size of locality, size of household, literacy, and labor force. Of particular interest is table 11, which shows population figures by single years of age for each sex. But the statistics presented are not limited to those which have become available in the past decade. Table 4, for example, gives for each of 198 geographic areas the population at every census taken since 1850; for many of these areas intercensal rates of increase are shown.

The second part of the *Demographic Yearbook* is devoted to international vital statistics. The tables on natality show both the number of live births and the rates according to age of mother and order of birth. About 75 pages are taken up with mortality statistics, subdivided by age, sex, and cause of death. The most recent available data on expectation of life for 62 geographic areas are given by age, separately for males and females. Unfortunately, such data are not available for large areas of the world—China, for example—while in other areas they are dated; the latest life table for the U. S. S. R. is for the years 1926-27 and relates only to the European part.

International comparability of demographic data is often impaired because of differences from one country to another in the concepts and procedures used in collecting, recording, and tabulating population data and vital statistics. The technical notes on the statistical tables in the *Yearbook* are invaluable for evaluating the quality and comparability of such data. Another useful feature is the detailed bibliography of recent official publications containing census and other demographic statistics for each area of the world.

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Hormones and the Aging Process. Edited by EARL T. ENGLE and GREGORY PINCUS. 323 pp. Academic Press, Inc., New York, 1956.

Many of the experiences in endocrinology have been derived from studies of complete exclusion of the hormones and from the administration of excessive amounts of these agents. By contrast, the conference reported in the work under review dealt with the more subtle questions of hormonal regulation in relation to aging and chronic stress. No attempt was made to define an "aging process."

Outside of regression of the gonads in females, no aspect of aging could unequivocally be assigned to a hormonal cause. However, for sex steroids, adrenal cortical steroids, thyroid hormones, related fields of calcium and protein metabolism, and water and electrolyte regulation, a considerable body of evidence is presented which speaks for a characterization of aging by such biochemical dimensions. In many instances the regulatory nature of these endocrine changes with time and aging was explored. The process of involution of the ovaries was shown to be in the gonad itself and not in a failure of pituitary stimulation or tissue response to the sex steroids. Similarly the changing pattern of adrenal cortical steroid production is not related to a failure of production of pituitary ACTH. There appears to be a changing economy for such adrenal hormones with less "needed" and less produced. This would speak for an adequate retention of pituitary-adrenal regulation, adapting to the changing bodily status with age. Thyroid function is diminished in later adult life but tissue capacity to respond to the hormone remains. In similar fashion a variety of changing metabolic activities are related to altered hormonal and non-endocrine influences such as general activity, appetite, nutrition, etc.

The recurring question raised by each report is whether these hormonal changes are the result of or the cause of the aging phenomena. As presented, the failure of "hormonal replacement therapy" to repair more than isolated aspects of the defects of aging is in keeping with the need for more extensive understanding along such lines. The need for considering individual differences in status as opposed to chronological age, past history of chronic stresses, degree of tissue changes, associated degenerative or neoplastic diseases, etc. in extensions of the work is clearly indicated in the discussions reported. All this is in keeping with the opening remarks of the editors who present both the convening of the conference and this report "as stimulants to obviously needed investigation" in a difficult and neglected field.

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The Direction of Human Development: Biological and Social Bases. By M. F. ASHLEY MONTAGU. ix + 404 pp. New York: Harper & Bros., 1955. $5.00.

The author claims the content of this book to be "the most dramatic and important experience" of his life. The publisher refers to it as an "unprecedented assembly" of research data from biology, physiology, medicine, psychology, sociology, education, anthropology, and related fields which sets forth the "heavy weight of evidence to affirm the necessary role of cooperation and affection in the life of the individual in society." After such promise, this reviewer was badly let down!

In his Foreword the author anticipates criticism. He states that he has omitted much evidence for his various claims; he admits freely to the charge of over-simplification but believes his message sufficiently dramatic and important at the present time to warrant this attempt to demonstrate the categorical imperatives of love and of cooperation in man's social life.

Anything like an adequate critical review would examine in detail the author's use of such a tremendous volume of research literature. The author has, indeed, read widely and fruitfully; he has written boldly as he has attempted to weave together this great mass of material from more than 700 references. Such an heroic undertaking is bound to find criticism at the hands of the less courageous.

The theme of the book is an extension of an idea which Professor Montagu has advanced before—that the end to which all nature strives is social cooperation; that the basic and most powerful motive in human experience is love; that human development trends in the direction of greater cooperation and greater social cohesiveness; that man should profit from the lesson of his evolutionary heritage and aid rather than hinder this development. The author rejects out of hand the idea that human nature is morally neutral. Human beings are born good—"'good' in the sense that there is no evil or hostility in them, but that at birth they are wholly prepared, equipped, to function as creatures who not only want and need to be loved by others, but who also want and need to love others." (p. 289) Herein is a reaffirmation of Rousseau and the English romantic poets of a later day. Thus the book might be viewed as a humanistic counter move to the dictation of despair which crowds our literature at the present time, finding in man a grim existential character or at least a dual nature, with the death wish as prominent as the life wish.

This reviewer is less concerned with the admitted over-simplification and the omission of additional evidence than with two other flaws:

The evidence adduced is uncritically handled. A homely antecdote from a popular magazine on child care is quoted with as much conviction and considered as significant as a carefully controlled scientific study published in a scholarly journal. For purposes of scientific evidence, the author makes no distinction among a clinical record of one case, a carefully controlled laboratory experiment, an experiential anecdote, and sheer speculation.

The evidence adduced is selected to support the main thesis. The author offers experimental evidence supporting his general thesis and omits equally adequate evidence tending to confound it. For example, he describes Levy's well known puppy experiment at some length to show that reinforcement of the sucking drive follows frustrating that drive; he omits the important work of Brodbeck and Sears, and of others, showing that sucking resembles a learned response rather than an innate drive, and is weakened, not strengthened, by disuse. The text gives much space to Ribble's discussions of the importance of early nurturing experience of infants, but pays no attention to the counter evidence and sharp criticisms which have been advanced against this point of view.

That developmental processes exhibit directionality is an insistent idea—one not easily put aside, even by the most ateleological of scientists. But writers such as Sinnott or Lillie stay fairly close to the material with which they are most familiar.

There is need for synthesis, and the man who attempts to view the scattered fragments of evidence from various fields so as to discern the pattern always hazards sharp criticism. His "theory" which fills the gaps between the known and plotted areas should, however, be subject to test. Montagu's book is a statement of a faith, not a theory. The frankly evangelical tone of the book may make it more suitable for the trade than for science.

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Proceedings of the World Population Conference, 1954, Rome, 31 August—10 September 1954. Volume I, xiii + 1040 pp. United Nations, New York, 1955. $1.50.

This is the first of six volumes of papers presented at the World Population Conference held in Rome in 1954 under the auspices of the United Nations with the close collaboration of the International Union for the Scientific Study of Population, the Food and Agriculture Organization of the United Nations, the International Bank for Reconstruction and Development, the International Labor Organization, the United Nations Educational Scientific and Cultural Organization, and the World Health Organization. This volume contains the papers presented at Meetings 2, 4, 6 and 8 which dealt with mortality and fertility trends. Meeting 2 was devoted to mortality trends with special attention to areas of lower mortality while Meeting 4 was concerned with areas of higher mortality. Meetings 6 and 8 represent a similar dichotomy in relation to fertility trends. Of the 69 papers presented at the four meetings 49 were in English, 13 in French, 5 in Spanish and 1 each in German and Chinese. Each paper is followed by a short summary in English and French. The papers have been reproduced by photo-offset from typescript.

Countries in all parts of the world and a number of international organizations are represented among the authors. Within the field covered, the papers treat a wide range of subject matter, including methodological concepts, analyses of birth and death statistics for individual countries and regions, and future projections of mortality and fertility trends. It is obviously impossible in a brief review to do justice to a compilation of this kind, but there are a few important conclusions which emerge from a general review of the various papers. In most of the areas of high mortality for which data are available a spectacular decline has occurred during the past decade. As this has not been accompanied by comparable declines in fertility, substantial population increases have resulted. In areas of low mortality there has been a further but more moderate decline. In almost all cases this has been greater for females than for males. As mortality rates of females were already lower, a widening mortality differential between the sexes has resulted.

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Structure of the Ego. By L. LANGSTROTH. 149 pp. Stanford University Press, 1955. $4.00.

The first third of the book is concerned with a description of the psychology of Otto Rank and its application to psychoanalytical treatment. It culminates in Rank's will psychology. Will and opposing will, and the earlier discussed concepts of oral sadism and libido and the social and biological self are said to explain personality and behavior. Will and opposing will are abstractions. It is through the art of interpretation "that we are able to tread a path through the mass of projections, rationalizations, and denials that go by the name of thought." (p. 34) This may be so, and it is quite possible that we do not have at present a better way of dealing with the complexities of human nature than by using crude concepts such as positive and negative identification, denial, sado-masochistic mechanisms, etc. If, however, the author speaks of forces that emanate from the nuclei in the ego structure or illustrates his psychological concepts by writing, "The will arises in the id but does not become conscious till it reaches the realm of feeling, where its content is evaluated by its feeling quality" (p. 34), the reviewer will be pardoned for not trusting Langstroth's critical abilities. Langstroth then proceeds to assign certain anatomical structures to immensely complex psychological phenomena as illustrated by the following quotations: "The will force would pass to the postcentral gyrus by the connections between the VPL nucleus and this sensory area, the opposing will or DM nucleus supplying the majority of the fibers and the conscious will or AV nucleus the minority," etc. (page 51); "If the term 'suppression' can be used to indicate a lessening of the height of contraction or a mollification of tension, then a good case can be made out for identifying the 'suppressor' bands as cortical areas where the opposing will, as represented by the DM nucleus, and the feeling content of the conscious will meet in continual interplay" (p. 85-86); "The opposing will is allocated to the DM nucleus and the feeling component of the conscious will to the suppressor band (Area 4s)" (p. 95). Modern investigators who base their conclusions on neurophysiological and psychological experiments on animals with brain lesions and on the critical evaluation of clinical cases are very hesitant to assign a precise localization to less complex functions than Langstroth discusses in this book. He adheres to a psychology that is akin to the faculty psychology of Thomas Reid (1785) and combines it with recent anatomical data without giving a shred of evidence for the justification of such an audacious undertaking.

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The Biology of the Spirit. By EDMUND W. SINNOTT. Pp. ix + 180. New York: The Viking Press, 1955. $3.50.

Is there anything a scientist, applying the methods of science, can usefully say about the spirit, the soul, God? Is there *any* method by which he can render these intangibles tangible? This book is an answer to those questions. Writing with admirable clarity, with courage and humility, Dr. Sinnott expounds the hypotheses which, he believes, are capable of returning reasonable answers to the above questions, and also—by no means incidentally, throwing some light upon the nature of man and his relation to the universe in which he finds himself.

For many reasons the book ought to make a wide appeal to scientists. In the first place, it is relatively short; in the second place, it asks the old questions not as a dogmatist but as a scientist would ask them, and it attempts to return the answers in the light of contemporary scientific understanding; third, the book is not overburdened with the apparatus of learning; and finally, the author uses his words with caution. Hence, whether the reader will agree on all points with Dr. Sinnott or not is of no great moment—what the reader will find himself benefiting from is the experience of being fairly and squarely faced with certain elementary questions and the necessity of critically evaluating Dr. Sinnott's arguments in support of his hypotheses.

As a general rule scientists adopt a rather lazy agnostic viewpoint. The nineteenth century is generally taken to have cooked the theologian's goose and, if the latter's ghost occasionally rises to plague them, the noises it makes tend to be rather contemptuously dismissed for what they are considered to be worth. This is the materialist attitude, and that it has already done not inconsiderable harm in the world is evident. Materialists and scientific humanists will not like Dr. Sinnott's book. Unlike Huxley he believes that purpose is inherent in the very nature of life, and that it is man's job not merely to make purposes but to discover what purposes are already inbuilt in the very structure of man. The notion that man is the resultant of a long history of chance occurrences is only too often confused with the idea that at birth the individual is nothing but a system of random impulses out of the disorder of which culture must make a semblance of order. What is overlooked is that the system, the *organism*, at birth is already a highly organized, ordered, system, which far from requiring the imposition upon it of an externally conceived system of order, requires the nourishment and stimulation, based on an understanding of its needs, which will cause it to grow and develop so that its potentialities shall be fully and harmoniously realized. "We are standing at an impasse in our basic philosophy and seem to be faced with a choice between the physical and the spiritual side of man as the final reality," writes Dr. Sinnott, and it is out of the study of growth and development of living things that he is led to the choice of the spirit. The biological fact of self-regulation, he believes, is equatable with the psychical, and the psychical, in man, is equatable with the spirit—"the mass of natural impulse, desires, and emotions that well up out of protoplasmic purposiveness, setting up in us goals and longings of all sorts, conscious or unconscious. These are native to our living stuff, though subject to elevation or debasement."

Somatic development and psychic development, as exhibited on the one hand by the tendency among living things to reach and maintain an organized living system, and on the other by persistent directiveness or goal-seeking, Dr. Sinnott sees as fundamentally the same thing, merely two aspects of the basic regulatory character displayed by all living stuff. Conscious purpose is the inner experience of protoplasmic goal-seeking. I do not suppose that Dr. Sinnott would deny that with the addition of culture that purpose becomes or is capable of becoming much more. The purposes of ameba and man spring from the same fundamental unity of protoplasmic stuff, at the functional level expressing themselves as the integrals of different levels of integration. Man is not merely a rational being but fundamentally a seeking, desiring, aspiring one. "From this comes the force that moves and guides him" and "gives hope of making our social order a far better one than it now is." "He who learns to remold the heart's desire, and not the mind's intent alone, will hold in his hands the key to our salvation."

In brief, what Dr. Sinnott is saying is that it is through science that we are learning that science is not enough, or as Pascal put it, the heart has its reasons of which the reason knows not. Some scientists, in the contemporary period, have for the first time in the history of science been inquiring into the heart's reasons, and they have come up with some astonishing findings. I am sure that Dr. Sinnott is familiar with much of this work, although he makes no direct reference to it, for it supports some of his arguments up to the hilt. "Love," concludes Dr. Sinnott, "is the climax of all goal-seeking, protoplasm's final consummation."

The system of goals and biological purposes which the organism constitutes would suggest the existence of a Principle of Organization—a principle which brings order out of randomness, spirit out of matter and personality out of neutral and impersonal stuff—thus providing the three great essentials for religion. The Principle of Organization lifted above its expression in matter into the realm of spirit, Dr. Sinnott believes, may be thought of as an attribute of God. "God . . . is that Power which creates organized living systems and sets up in them the goals toward which they move and culminate in the aspirations of the spirit."

This may sound like the old stand again, and in a very real sense it is, except that Dr. Sinnott speaks as a scientist, not as a dogmatist or authoritarian, but as a humble man thinking aloud as rigorously, as honestly, and as helpfully as he can. This is the contribution which he makes in this book. It will be read with the respect and gratitude that it deserves.

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BOOK NOTICES

NEUROPHARMACOLOGY. Edited by Harold A. Abramson. 210 pp. (1st conference), 328 pp. (2nd conference). The Josiah Macy, Jr. Foundation, New York, 1955, 1956. $4.25 each. The first conference was devoted to such topics as brain circulation and metabolism, functional organization of the brain, and electrical activity in relation to anesthesia. The second conference dealt more directly with "chemopsychology," defined as the study of the influence of chemical substances upon human behavior. Special attention was given to the effects of lysergic acid diethylamide.

SCIENCE IN PROGRESS. Edited by George A. Baitsell. xviii + 343 pp. Yale University Press, New Haven, 1955. $6.50. The current volume, ninth in the series established in 1939, contains papers by 10 outstanding scientists, presented in the framework of Sigma Xi National Lectureships. Particularly relevant are the contribution on human heredity by L. H. Snyder and George Wald's lecture on the molecular basis of visual excitation.

ALLGEMEINE THEORIE DER MENSCHLICHEN HALTUNG UND BEWEGUNG. By F. J. J. Buytendijk. 367 pp. Springer, Berlin, 1956. DM 40.0. In this comprehensive monograph a general theory of human posture and movement is offered as a combination of the physiological and psychological approach to the problem.

A STUDY OF THINKING. By J. S. Bruner, J. J. Goodnow, and G. A. Austin. xi + 330 pp. John Wiley, New York, 1956. $5.50. Records the outcome of a 5-year program of research on cognition carried on in the Laboratory of Social Relations at Harvard University and focussed on the phenomena of categorizing (conceptualizing). R. W. Brown contributed an appendix on applications to psycholinguistics.

LES MÉCANISMES CÉRÉBRAUX DE LA PRISE DE CONSCIENCE. By Paul Chauchard. 240 pp. Masson, Paris, 1956. Frs. 1,300. *Cerebral Mechanisms of Awareness* attempts to synthetize the contributions of 3 "schools" of neurophysiology: French (L. Lapicque), Russian (I. P. Pavlov), and English (C. Sherrington). The three parts deal with sleep, "neuro-consciousness," and implications for pathology.

TOWN AND COUNTRY IN BRAZIL. By Marvin Harris. x + 302 pp. Columbia University Press, New York, 1956. $4.50. Description of a small county seat in the mountainous region of eastern Brazil from the point of view of social anthropology.

IMMIGRANTS AND THEIR CHILDREN, 1850-1950. By E. P. Hutchinson. xiv + 391 pp. John Wiley, New York, 1956. $6.50. A volume in the Census Monograph Series, the book gathers information on the composition, geographical distribution and occupational stratification of U. S. population of foreign stock over the last 100 years, with emphasis on the changes since 1920.

NEBRASKA SYMPOSIUM ON MOTIVATION, 1956. Edited by Marshall R. Jones. viii + 311 pp. University of Nebraska Press, Lincoln, 1956. $3.00 paper, $3.50 cloth. Text and detailed discussions of 6 papers, covering a wide range of topics in the study of motivation (incl. "sex drive" and a neurological approach to motivation), originally presented at the 4th symposium on Current Theory and Research in Motivation, financed through a grant from the U. S. Public Health Service.

RESERPINE IN THE TREATMENT OF NEUROPSYCHIATRIC, NEUROLOGICAL AND RELATED CLINICAL PROBLEMS. Edited by F. F. Yonkman. Annals of the New York Academy of Sciences, Vol. 61, Art. 1, 280 pp., New York, 1955. $3.50. In addition to the therapeutic applications in a variety of situations, the volume enhances our understanding of the scope and nature of action of this important tranquilizing drug.

LA POBLACIÓN DE VERACRUZ. By Felipe Montemayor. 78 pp. Gobierno de Veracruz, 1950-1956. Following a brief survey of languages and population groups, the author presents the physical characteristics largely on the basis of Johanna Faulhaber's *La Antropología Física de Veracruz* (2 vols., 1950-1956).

BIOGRAPHICAL MEMOIRS. National Academy of Sciences. 359 pp. Columbia University Press, New York, 1956. $5.00. Of special interest are the biographies of two outstanding pioneers of scientific psychology, Raymond Dodge, the student of visual motor functions and of the *Conditions and Consequences of Human Variability* (Yale University Press, 1931), and Carl Emil Seashore who spent 50 years *On Search of Beauty in Music* (Ronald Press, 1947, with a fitting subtitle: *A Scientific Approach to Musical Esthetics*).

PEACEFUL USES OF ATOMIC ENERGY. Vol. 10, 11, 16, Proceedings of the International Conference in Geneva, August, 1955. 544, 402, 203 pp. United Nations, New York, 1956. $8., $8., $5. This important conference set several records, including the speed with which the materials are being made available. The history of the conference and the special evening lectures are presented in Vol. 16. Biological effects of radiation are considered in Vol. 10 and 11, including modes of radiation injury and effects on bones and reproductive system, protection and recovery, genetic effects, use of isotopes and nuclear radiations in the diagnosis and study of disease and in therapy.

BIOMETRIKA TABLES FOR STATISTICIANS. Edited by E. S. Pearson and H. O. Hartley. xiv + 238 pp. Cambridge University Press, New York, 1956. $4.50. Publication of this volume 42 years after the issue of Karl Pearson's *Tables for Statisticians and Biometricians* indicates a continuing need for devices which would "reduce the labour of statistical arithmetic." The present volume contains the more commonly used tables and will be followed by a second volume with more specialized tabular materials. There is a large introduction (100 pp.)

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE KNEE. By S. I. Pyle and N. L. Hoerr. viii + 82 pp. Charles C. Thomas, Springfield, 1955. $4.25. The first in the new series of radiographic standards of skeletal maturation, based on the Brush Foundation study, was published in 1950 (hand and wrist, by W. E. Greulich and S. Idell Pyle, Stanford University Press). In the second atlas the authors briefly describe the concept of skeletal age, define the anatomic and radiographic terms, and present 29 plates together with discussion of maturity indicators and developmental features for ages from birth to 18 years. An important standard of reference.

POLICE DRUGS. By Jean Rolin. Translated by L. J. Bendit. x + 194 pp. Philosophical Library, New York, 1956. $4.75. Pharmacology (and electrophysiology) hold keys to Pandora's box containing new techniques of "brain-washing." The author, fearful of the easy misuse of the "satanic pharmacopeia," condemns narco-analysis as a technique for interrogation and forcing confession.

ON THE NATURE OF MAN. By Dagobert D. Runes. 105 pp. Philosophical Library, New York, 1956. $3.00. A collection of philosophical essays and brief "evening thoughts" reflecting the author's belief that "in reading, sometimes less is more."

STATISTICAL METHODS. By George W. Snedecor. xii + 534 pp. Iowa State College Press, Ames, Iowa, 1956. $7.50. A time-tested guide (1st ed., 1937) for uses of statistics in biology. A chapter on sampling was contributed by W. G. Cochran.

HUMAN HEREDITY HANDBOOK. By Amram Scheinfeld. 276 pp. J. B. Lippincott, Philadelphia, 1956. $3.95. Written in a breezy style, the volume represents a useful guide to the subject of human inheritance, including medical considerations.

CLASSICS OF BIOLOGY. By August Pi Suñer. Translated by Charles M. Stern. x + 337 pp. Philosophical Library, New York, 1956. A survey of the major topics of theoretical biology, documented with extracts from the writings of authors from Plato and Aristotle to Erwin Schrödinger and Ludwig von Bertalanffy.

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INFORMATION FOR CONTRIBUTORS

HUMAN BIOLOGY, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of 8½ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne State University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

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References in the text to the literature should be made by using the author's name followed by the year of publication: " Studies of Garn and Saalberg ('53) . . ." At the end of the article, under the heading " LITERATURE CITED," full references with titles and inclusive page references should appear (double spaced) in alphabetical order of the authors' names: " GARN, S. M. AND J. H. SAALBERG 1953 Sex and age differences in the composition of the adult leg. Human Biol., *25:* 144-153."

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a record of research

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THE GEOGRAPHIC DISTRIBUTION OF CEREBRAL HEMORRHAGE AND HYPERTENSION IN JAPAN

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IN Japan, tuberculosis was the most outstanding cause of death for a long time, but since 1951 cerebral hemorrhage has taken its place. This seems very different from the situation in Occidental countries where heart diseases are the chief causes of death. Both cerebral hemorrhage and heart diseases, however, are caused mostly by the same high blood pressure.

Hashimoto and others ('33) report that hypertension is by no means rare among urban Japanese among whom it is found nearly as frequently as among Americans or Europeans, as against almost all reports of other areas in the Far East which indicate a low mean blood pressure. In rural Japan, also, it is well known that there are geographic differences in the prevalence of hypertension; it is generally high in the prefectures of the northeast part of the main island. We have studied blood pressures especially of farm-villagers in such prefectures

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as Aomori and Akita. It is well-known in this country that the latter have the highest death rate from cerebral hemorrhage in all Japan.

In the present paper the geographic distribution of death rates from cerebral hemorrhage in middle age is described. We find that the middle-age death rate is the most appropriate one to investigate in respect to geographic distribution of cerebral hemorrhage in Japan, especially in the field of public health. In older age classes the death rate is naturally higher, and the proportion of population over 60 years varies considerably among different provinces; therefore, if the population studied contains the older age group also, the death rate may vary with the proportion of older people. In younger age classes cerebral hemorrhage usually has other origins than so-called essential hypertension, especially in the newborn where it comes from birth injury; younger ages are therefore also excluded from consideration.

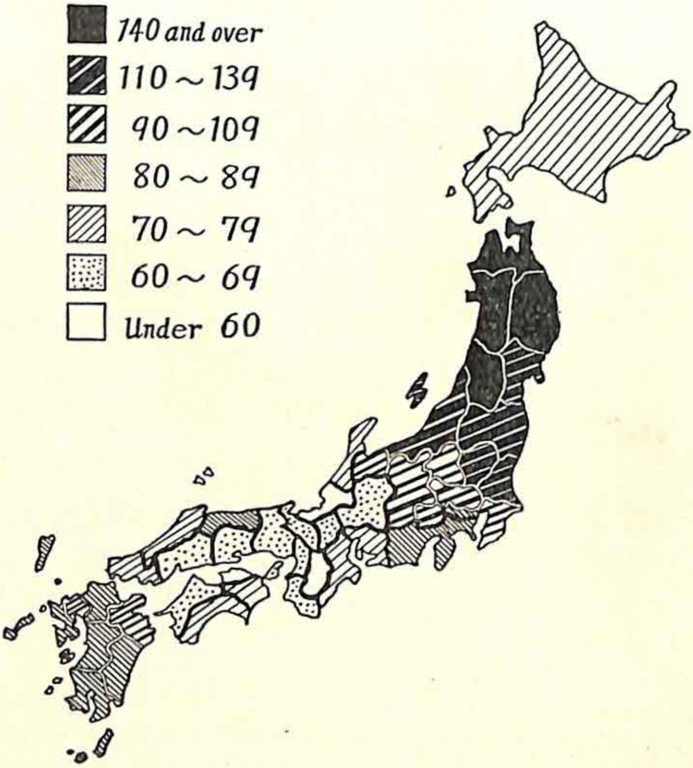

FIG. 1. DISTRIBUTION OF MIDDLE AGE (30–59 YEARS) DEATH RATE FROM CEREBRAL HEMORRHAGE BY PREFECTURES IN JAPAN, 1950, MALE.

There are, unforunately, few reliable data, classified by sex and age classes, on the mean blood pressure or the prevalence of hypertension in various populations of different provinces. Though there is voluminous data on average blood pressure of holders of insurance policies for Japan as a whole, we have compared our own data mainly with the results of other local studies.

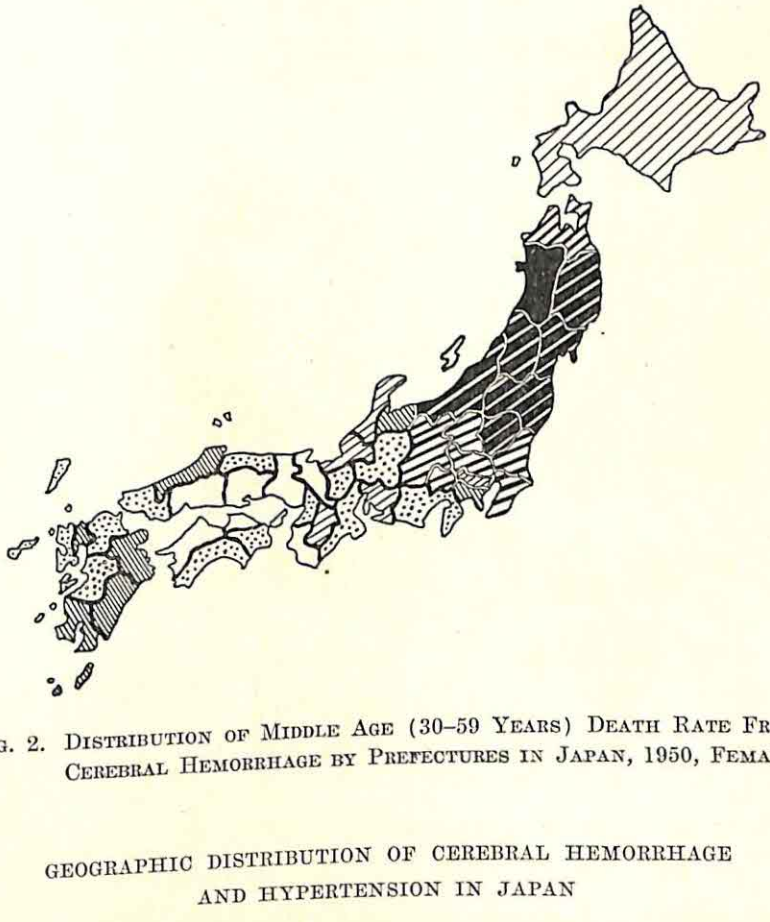

FIG. 2. DISTRIBUTION OF MIDDLE AGE (30–59 YEARS) DEATH RATE FROM CEREBRAL HEMORRHAGE BY PREFECTURES IN JAPAN, 1950, FEMALE.

GEOGRAPHIC DISTRIBUTION OF CEREBRAL HEMORRHAGE AND HYPERTENSION IN JAPAN

In figures 1 (male) and 2 (female) the geographic distribution of cerebral hemorrhage per 100,000 persons aged 30 to 59 is plotted. The data is listed under "vascular lesions affecting central nervous system"—international abbreviated list number, B22—in the governmental Vital Statistics for 1950. The death rate is calculated for each of the 46 administrative prefectures into which Japan is divided.

TABLE 1

Blood pressure of different provinces in Japan, Male (averages and standard deviations)

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	NUMBER		AGE CLASS, YEARS 20–29	30–39	40–49	50–59	60–69	70–79
1.	Hokkaido, Farm villagers	Sakuma	1948 Summer	235	Systolic	122.8± 9.7	128.9±10.5	133.7±10.9	142.9±13.1		
2.	Hokkaido, Farm villagers	Otokozawa	1952	195	Systolic	123.2±10.2	126.6± 9.4	133.8±10.6	143.6±11.2		
3.	Hokkaido, Postal service workers	Maruyama	1953	893	Systolic	129.1±14.6	128.1±14.1	131.3±17.5	138.9±24.7	143.9±22.8	
4.	Aomori, Farm villagers	Takahashi, Sasaki, Takeda and Ito	1954 Summer	307	Systolic Diastolic	128.3±12.5 68.6±11.6	130.2±12.2 76.5±11.4	136.4± 8.6 80.1±12.0	139.9±21.9 82.2±15.5	163.1±33.2 92.0±18.7	165.5±26.2 89.0±19.1
5.	Akita, Farm villagers	Takahashi, Sasaki, Takeda and Ito	1955 Summer	286	Systolic Diastolic	131.9± 9.8 67.3±11.2	140.0±19.5 75.5±14.6	144.5±25.1 80.7±17.7	158.6±28.6 90.1±16.3	163.8±27.9 89.8±14.6	180.0±31.0 92.5± 8.3
6.	Akita, Farm villagers	Takahashi, Sasaki Takeda and Ito	1955-1956 Winter	204	Systolic Diastolic	137.7±10.1 66.8±13.4	145.4±26.9 79.4±15.9	157.9±29.0 87.3±15.2	173.3±28.0 93.5±16.4	175.2±33.3 93.1±16.9	186.7±37.1 101.7±18.9
7.	Akita, Farm villagers	Fukuda *et al.*	1951-1953 Summer	2082	Systolic Diastolic	131.8±15.2 78.4±13.9	132.9±15.5 81.8±13.5	140.8±24.4 86.9±17.5	152.6±29.0 94.2±17.6	161.8±28.7 96.0±17.9	165.0±29.6 95.1±17.7
8.	Aomori and Akita (partly), Postal service workers	Araya	1955 Summer	566	Systolic	119.4±13.1	123.1±11.2	132.0±21.5	137.1±22.4	146.4±25.0	
9.	Chiba, Farm villagers	Donomae and Matsumoto	1943 Summer	A 490 B 663 C 311	Systolic " "	131.1±15.2 122.4±13.2 120.7±19.1	132.3±13.1 124.2±14.5 124.3±11.3	140.6±18.8 126.5±16.0 126.9±13.4	144.4±23.8 132.7±24.5 137.0±20.3	160.5±26.8 145.2±29.2 146.2±34.9	163.7±26.6 149.4±25.6 166.4±26.1
10.	Tittori, Farm villagers	Nishimura *et al.*	1946 Summer	185	Systolic Diastolic	110.1 58.4	104.4 57.8	110.9 65.6	105.2 61.6	120.2 66.0	
11.	Okayama, Farm villagers	Ōshima	1954 Summer	235	Systolic Diastolic	104.0±10.5 60.1± 9.0	105.0±15.5 61.3±11.1	109.2±12.2 68.3±10.6	121.7±28.3 75.0±14.4	124.8±24.5 75.4±10.7	

Notes: Hokkaido is the northern island; Aomori and Akita Prefecture are north, Chiba is middle east, Tottori and Okayama are west in the main land, Kagoshima is south in Kyushu. Numbers following ± mean standard deviation of blood pressure. Average blood pressure of nos. 7 and 10 is caluculated from the data of the authors.

TABLE 2

Blood pressure of different provinces in Japan, Female (averages and standard deviations)

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	NUMBER		AGE CLASS, YEARS 20–29	30–39	40–49	50–59	60–69	70–79
1.	Hokkaido, Farm villagers	Sakuma	1948 Summer	576	Systolic	117.9±11.6	121.3±12.9	124.6±16.0	137.1±14.3		
2.	Hokkaido, Farm villagers	Otokozawa	1952 Summer	324	Systolic	122.5±11.9	125.3±13.7	133.9±11.8	140.5±15.8		
3.	Hokkaido, Postal service workers	Maruyama	1953 Summer	269	Systolic	124.8±13.2	125.0±13.0	127.0±15.8	132.0±14.8		
4.	Aomori, Farm villagers	Takahashi Sasaki, Takeda and Ito	1954 Summer	376	Systolic Diastolic	125.3±11.8 68.8±10.6	128.5±13.2 77.5±10.0	137.7±23.1 82.8±13.4	147.3± 9.6 85.1±15.7	163.0±30.1 89.7±16.7	168.2±28.7 92.2±15.1
5.	Akita, Farm villagers	Takahashi, Sasaki, Takeda and Ito	1955 Summer	386	Systolic Diastolic	136.8± 9.4 79.6±10.8	142.3±17.4 81.9±17.7	152.1±27.8 85.6±14.8	162.8±27.6 87.6±12.9	165.4±25.2 88.9±15.7	193.0±23.2 97.0±14.7
6.	Akita, Farm villagers	Takahashi, Sasaki, Takeda and Ito	1955-1956 Winter	303	Systolic Diastolic	138.7±17.3 74.4±16.8	150.6±31.2 83.5±17.0	151.6±27.6 84.8±12.8	169.0±34.6 90.9±16.0	178.6±29.4 94.6±14.0	212.5±33.1 100.0±14.1
7.	Akita, Farm villagers	Fukuda *et al.*	1951-1953 Summer	3219	Systolic Diastolic	128.8±16.6 75.6±21.5	134.2±21.0 85.6±15.0	141.3±23.5 90.0±16.5	149.1±27.4 91.7±16.0	162.2±28.3 96.1±17.7	172.1±27.7 96.9±18.1
9.	Chiba, Farm villagers	Donomae and Matsumoto	1943 Summer	A 643 B 815 C 433	Systolic " "	126.3±14.4 121.9±15.1 123.3±14.3	134.9±18.0 124.6±15.2 125.2±11.5	142.9±22.1 129.2±20.2 134.0±22.9	145.9±23.7 136.8±27.5 139.9±24.6	151.9±30.0 144.2±26.8 152.1±23.6	172.1±30.4 156.2±25.1 157.5±22.2
10.	Tottori, Farm villagers	Nishimura *et al.*	1946 Summer	225	Systolic Diastolic	103.6 61.0	107.0 62.0	113.3 67.2	123.5 72.4	128.1 70.2	
11.	Okayama, Farm villagers	Ōshima	1954 Summer	241	Systolic Diastolic	104.2± 5.8 61.2±13.4	103.3± 6.7 64.6±11.5	110.4±10.2 72.8±12.8	121.7±10.4 72.1±11.0	139.2±15.9 77.8±14.7	

The figures clearly show that the middle-age death rate from cerebral hemorrhage is lower in the southwest, especially in the prefectures surrounding the Inland Sea, Seto, and higher in the northeast, with the exception of Hokkaidō where the rate is lower than average, than in all the rest of Japan.

Before World War II statistics of arterial pressure based on mass surveys of the population, except that of insurance policy holders were rare. During and immediately after the war, Shimizu *et al.* ('50), Watanabe ('54) and other authors pointed out a decrease of average arterial pressure (especially systolic) similar to that shown in Occidental countries. This fact must be considered in comparing the data of nos. 9 and 10 in tables 1 and 2 with the later studies summarized in the table. Series in tables 1, 2 and 3 were all measured by the auscultatory method with mercury sphygmomanometer, except nos. 8 and 10, which were measured by Tycos sphygmomanometer. Chiefly, data measured in summer are compared with each other in the tables, because of seasonal differences in average blood pressure in Japan and because differences of atmospheric temperature in different provinces are smaller in summer than in winter as shown in figure 3. Farm-villagers are the subjects of most data in tables 1 and 2; farmers and related workers are usually native, and according to the result of the census in 1950, they are the major occupational group—almost half of all working people—and are distributed evenly in all provinces except in the big cities. Living conditions of farmers are simpler than those of other citizens. Data for other occupational groups is given in some cases where that for farmers is lacking.

In tables 1 and 2 mean blood pressure is followed by standard deviation, (not standard error nor probable error). The distribution of blood pressure, especially in the older age class, is not always normal.

By comparing the data of tables 1 and 2 with that of figures 1 and 2 one can see that the distribution of average blood pressure tends to parallel that of the middle age death rate from cerebral hemorrhage. The tables, however, lack appropriate data for the south and are considerably incomplete. In tables 1 and 2 the average blood pressure of no. 11 seems too low, as if it were in the tropics. In this group a random sample among farmers, of about 50 persons for every 10 year age class, was measured in midsummer. The average blood pressure of farm-villagers in the neighboring prefecture, Tottori, is also low (no. 10 in tables 1 and 2); however, it was measured in a period of

TABLE 3

Average blood pressure in Kagoshima, Male and Female

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	NUMBER		AGE CLASS, YEARS			
						20–29	30–39	40–49	50–59
12.	Kagoshima,	Sato *et al.*	1951	801	Systolic	113.0	114.4	117.0	124.0
	Sales workers,		Summer		Diastolic	59.7	67.5	68.8	78.3
	Clerks,		1952	1309	Systolic	117.8	112.8	131.5	137.1
	Students, etc.		Winter		Diastolic	71.7	70.4	92.8	105.9

food shortage, just after the war. In the distribution of the death rate from cerebral hemorrhage, Okayama Prefecture and the other prefectures surrounding the Inland Sea, Seto, show low values and the low average of blood pressure in this region may be significant.

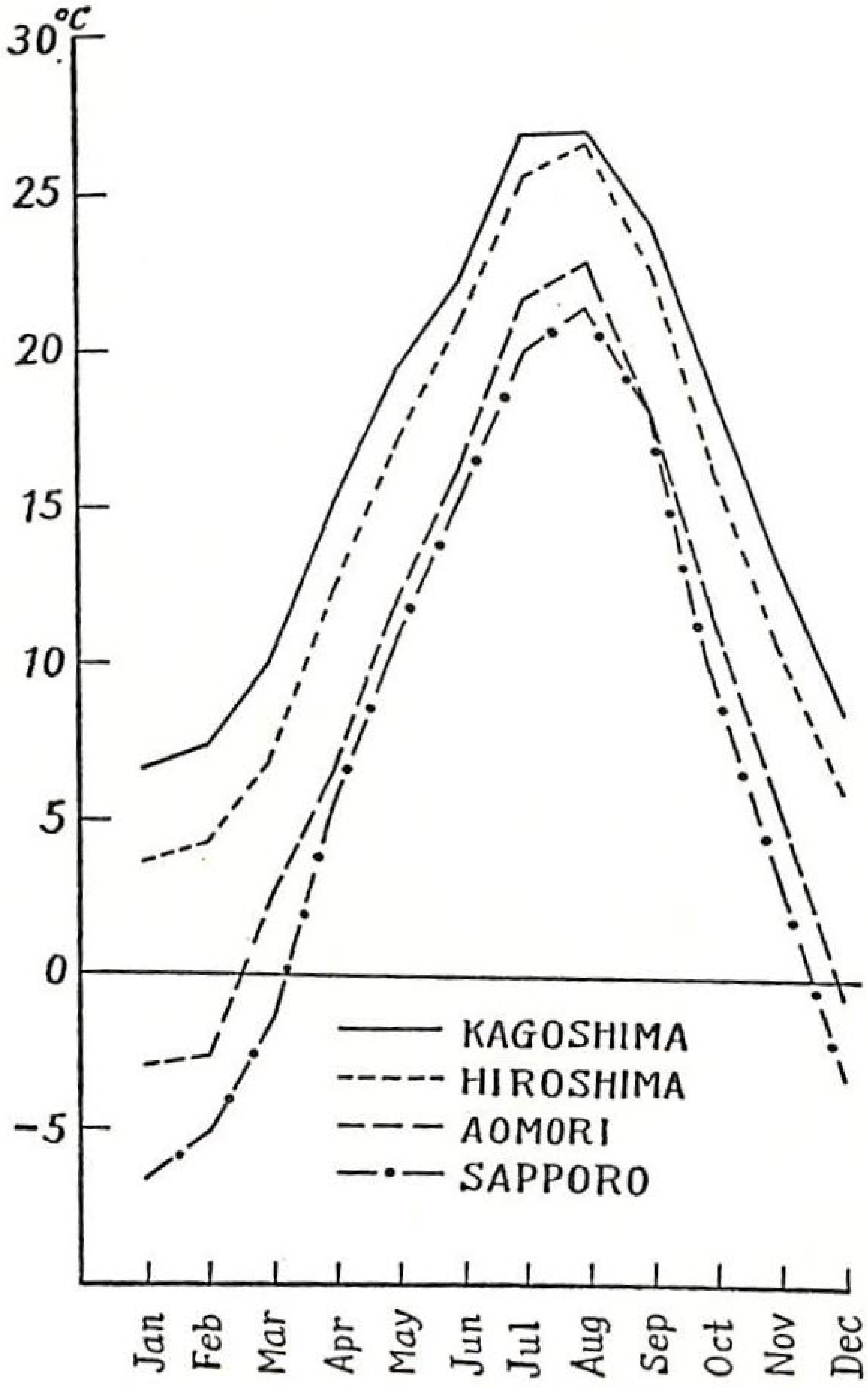

FIG. 3. MONTHLY AVERAGE TEMPERATURE IN KAGOSHIMA (IN KYŪSHŪ), HIROSHIMA, AOMORI, AND SAPPORO (IN HOKKAIDŌ).

In Japan, blood pressure readings in the brachial artery elevated to 150 mm Hg and above, systolic, and 90 mm Hg and above, diastolic, are usually regarded as hypertension, but sometimes a standard of 140 mm Hg is used as a borderline between normal and high blood pressures, especially in the south, and sometimes a standard of 160 mm Hg is used, especially in the north.

TABLE 4

Percentage and its standard error of persons whose blood pressure is 150 mm Hg and above Systolic and 90 mm Hg and above Diastolic, in various provinces

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	SEX, NUMBER		AGE CLASS, YEARS					
						20–29	30–39	40–49	50–59	60–69	70–79
1.	Aomori, Farm villagers	Takahashi *et al.*	1954 Summer	M, 307	Systolic	5.6± 3.8	6.5±3.6	21.6±4.8	26.4±5.2	61.0± 6.3	65.6±10.6
					Diastolic	0	8.7±4.2	18.9±4.5	31.9±5.5	47.5± 6.4	35.6±10.7
				F, 376	Systolic	2.9± 5.9	7.0±3.4	26.0±4.5	38.7±5.1	60.6± 5.8	68.0± 9.3
					Diastolic	0	7.0±3.4	28.1±4.6	30.1±4.8	46.5± 5.9	52.0±10.0
			1955 Summer	M, 286	Systolic	0	22.7±8.9	30.7±5.2	49.5±4.9	65.7± 5.8	100.0
					Diastolic	0	18.2±8.2	20.0±4.6	44.8±4.9	47.8± 6.1	50.0±25.0
				F, 386	Systolic	9.1± 8.7	22.7±8.9	38.8±4.3	62.7±3.9	75.4± 5.2	100.0
					Diastolic	9.1± 8.7	18.2±8.2	29.5±4.0	39.3±4.0	44.9± 6.0	60.0±21.9
2.	Akita, Farm villagers	Takahashi *et al.*	1956 Winter	M, 204	Systolic	9.1± 6.1	40.7±9.4	56.3±7.1	74.6±5.6	76.2± 6.5	83.3±15.2
					Diastolic	4.5± 4.4	25.9±8.4	37.5±7.0	61.0±6.3	64.3± 7.4	66.7±19.1
				F, 303	Systolic	25.0±10.8	31.7±7.2	47.0±5.4	66.7±4.5	86.0± 4.9	100.0
					Diastolic	18.7± 9.8	21.9±6.5	30.1±5.0	45.7±4.9	60.0± 6.9	75.0±15.3
3.	Kagoshima, Sales workers, Clerks, Students, etc.	Sato *et al.*	1951 Summer	M + F, 802	Systolic	0.6± 0.4	0.5±0.5	3.2±1.4	8.9±3.8	20.0± 8.9	
			Winter	M + F, 1309	"	0.7±0.3	2.1±0.9	3.2±1.4	12.5±4.0	47.4±11.5	

Note: M: male, F: female.

Numbers following $\pm = \sqrt{\frac{p(100 - p)}{N}}$, in which $p =$ prevalence rate (percent of the hypertensions), $N =$ number.

TABLE 5

Percentage and its standard error of persons whose Systolic blood pressure is 140 mm Hg and above in various provinces

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	SEX, NUMBER	AGE CLASS, YEARS 20–29	30–39	40–49	50–59	60–69	70–79
4.	Hokkaido, Postal service workers	Maruyama	1953 Summer	M, 893	21.9	17.5	25.2	45.1	50.0	
				F, 269	11.1	11.8	18.9	20.0	27.3	
5.	Aomori, Farm villagers	Takahashi *et al.*	1954 Summer	M, 307	13.9± 5.8	17.4± 5.6	43.2±5.8	43.1±5.8	72.9± 5.8	85.0± 8.0
				F, 376	11.8± 5.5	21.1± 5.3	42.7±5.1	46.2±5.2	73.2± 5.3	84.0± 7.3
			1955 Summer	M, 286	23.1±11.7	40.9±10.5	45.3±5.7	71.4±4.4	77.6± 5.1	100.0
				F, 386	36.4±14.5	50.0±10.7	61.2±4.3	78.0±3.4	84.1± 4.4	100.0
6.	Akita, Farm villagers	Takahashi *et al.*	1956 Winter	M, 204	45.5±10.6	59.3± 9.5	72.9±6.4	84.7±4.7	83.3± 5.8	83.3±15.2
				F, 303	43.8±12.4	53.7± 7.8	61.4±5.3	81.9±3.8	92.0± 3.8	100.0
7.	Aomori and Akita (partly), Postal service workers	Araya	1955 Summer	M, 566	8.9± 4.2	8.2± 3.0	27.7±2.8	39.5±1.3	54.3± 8.3	
8.	Okayama, Farm villagers	Oshima	1954 Summer	M, 235	0	4.2± 2.9	2.1±1.4	21.7±6.1	21.7±6.1	
				F, 241	0	0	8.2±3.8	25.0±6.3	37.3±6.8	
9.	Ōita, Postal service workers	Okamoto	1954 Summer	M + F, 2723	4.1± 0.6	3.2± 0.7	9.6±1.2	18.3±2.4	25.9± 8.4	
10.	Kagoshima, Sales workers, Clerks, Students, etc.	Sato *et al.*	1951 Summer	M + F, 802	1.1± 0.6	1.9± 0.9	5.7±1.8	14.3±4.7	40.0±11.0	
			Winter	M + F, 1309	3.1± 0.6	4.6± 1.4	15.6±2.7	39.1±6.1	68.4±10.6	

Note: Ōita Prefecture is in northeast Kyushu.

TABLE 6

Percentage and its standard error of persons with low blood pressure (Systolic, under 100 mm Hg)

NO.	PREFECTURE, KIND OF SUBJECTS	OBSERVERS	YEARS, SEASON	SEX, NUMBER	AGE CLASS, YEARS 20–29	 30–39	 40–49	 50–59	 60–69	 70–79
1.	Hokkaido, Postal service workers	Maruyama	1953 Summer	M, 893 F, 269	0.7 0	0.9 3.1	2.1 5.0	2.7 0		
2.	Aomori, Farm villagers	Takahashi *et al.*	1954 Summer	M, 307 F, 376	2.8±2.7 0	0 0	0 2.1±1.5	0 1.1±1.1	0 0	0 0
3.	Akita, Farm villagers	Takahashi *et al.*	1955 Summer	M, 286 F, 386	0 0	0 0	0 0	0 0	0 0	0 0
4.	Aomori & Akita (partly), Postal service workers	Araya	1955 Summer	M, 566	22.2±6.2	9.4±3.0	7.6±1.7	7.2±2.1	5.7±3.8	
5.	Okayama, Farm villagers	Ōshima	1954 Summer	M, 235 F, 241	34.0±6.8 35.6±7.1	41.7±7.1 39.6±7.1	18.8±5.6 34.7±6.7	23.9±6.3 14.6±5.1	6.5±3.6 7.8±3.7	
6.	Ōita, Postal service workers	Okamoto	1954 Summer	M + F, 2723	10.7±0.9	16.3±1.4	15.3±1.5	11.2±2.0	10.7±5.9	
7.	Kagoshima, Sales workers, Clerks, Students, etc.	Sato *et al.*	1951 Summer Winter	M + F, 802 M + F, 1309	17.6±2.0 7.9±0.9	25.6±3.0 11.3±2.0	21.5±3.3 8.4±2.2	14.3±4.7 0	15.0±8.0 0	

Tables 4 and 5 show rate of prevalence of hypertension in the same cases as tables 1, 2 and 3. These tables show the same tendency as are indicated in tables 1 and 2; namely, the prevalence of hypertension is higher in the northern prefectures, such as Akita and Aomori, and lower in the southern prefectures, such as Okayama, Ōita, and Kagoshima. In table 6, the proportion of low blood pressure—under 100 mm Hg, systolic—is seen to be very low in the north and higher in the south.

We have also tabulated data for postal service workers in three districts: Hokkaidō (district of Sapporo), Aomori and Akita (district of the west part of Aomori Prefecture and the northern part of Akita Prefecture), and Ōita (district of Beppu). The average blood pressure of the postal service workers seems a little lower than that of farm-villagers in Hokkaidō and Aomori and Akita prefectures, especially of those over 39 years of age. There is no big difference between postal workers in Hokkaidō and those in Aomori and Akita prefectures in respect to percentage of persons whose blood pressure show 140 mm Hg and above; on the contrary Ōita clearly shows a lower percentage. Low blood pressure, under 100 mm Hg systolic, is scarcely found in farm-villagers in Aomori and Akita prefectures; in postal service workers it is found in every age class, though the percentage is small. The percentage of low blood pressure in postal service workers is higher in Ōita Prefecture than in Hokkaidō or in Aomori and Akita prefectures.

THE CAUSE OF THE PECULIAR GEOGRAPHIC DISTRIBUTION OF CEREBRAL HEMORRHAGE AND HYPERTENSION

I. *The influence of atmospheric temperature.*

The territory of Japan consists of four main islands extending from northeast (about 45° N) to southwest (about 30° N). The death rate from cerebral hemorrhage is lower in the southwest and higher in the northeast except in Hokkaidō, as shown in figures 1 and 2. The distribution of the mean blood pressure of the people and the prevalence of hypertension among inhabitants seems to be parallel to the distribution of the death rate from cerebral hemorrhage.

The geographic distribution of cerebral hemorrhage and hypertension suggest that environmental factors may be a dominant cause. It is certain, of course, that genetic factors are in part responsible for the high blood pressure that is the basis of essential hypertension. But, genetic factors may not play so remarkable a rôle here as in the differences among different races, since the Japanese living in these provinces seems to belong to the same race, and are not notably different in body build. Even if there are some genetic differences among inhabitants of these provinces these differences should be ascribed mainly to selection and isolation for a long period of time. And then, also, environmental factors deserve consideration as a selecting factor.

It is very difficult to differentiate between the influence of genetic and environmental factors, since children usually live in their parents' houses and take the same customary diet. When children and parents have similar genetic susceptibility to hypertension and live always under similar pathogenetic circumstances tending to elevate arterial pressure, it is natural that, after a certain period, the children will get hypertension similar to that of their parents. There are provincial characteristics, not only in climate but also in the construction of houses, dietary customs, and other aspects of the manner of living. If there prove to be differences between provinces in cerebral hemorrhage or hypertension, these should not be interpreted simply as the result of the genetic factor. First we must investigate the environment.

Among environmental factors, climate seems to be first in applicability to the interpretation of the higher death rate from cerebral hemorrhage and the higher prevalence of hypertension in the northeast of Japan, except in Hokkaidō. In support of this argument note that the death rate from cerebral hemorrhage has a seasonal variation, as shown in figure 4. A significant difference between average blood pressure measured in summer and in winter was recognized in the same occupational group in Kagoshima, by Satō *et al.* ('52) as shown in tables 3, 4 and 5. Such a difference was also recognized by examining the same group of 199 individuals in Aomori Prefecture in both summer and winter (Takahashi *et al.*, '55). Mishima *et al.* ('53) found a tendency, in 4,214 male insurance applicants in Ōsaka and Kyōto, for the average blood pressure of people over 40 years of age measured in autumn and winter to be higher than that measured in spring and in summer. Monthly measurement of blood pressure in 16 young males by Ohashi ('48) in Yokosuka gave significant negative correlations between atmospheric temperature and blood pressure (systolic $r = -0.94$; diastolic $r = -0.92$, $P < 0.001$). Cold is the most general kind of stressor for people who live in the temperate zone; and the idea that repeated exposure to this environmental influence, which normally raises arterial pressure, eventually leads to a sustained hypertension is argued by Smirk ('49) and by Wolff and his colleagues ('51).

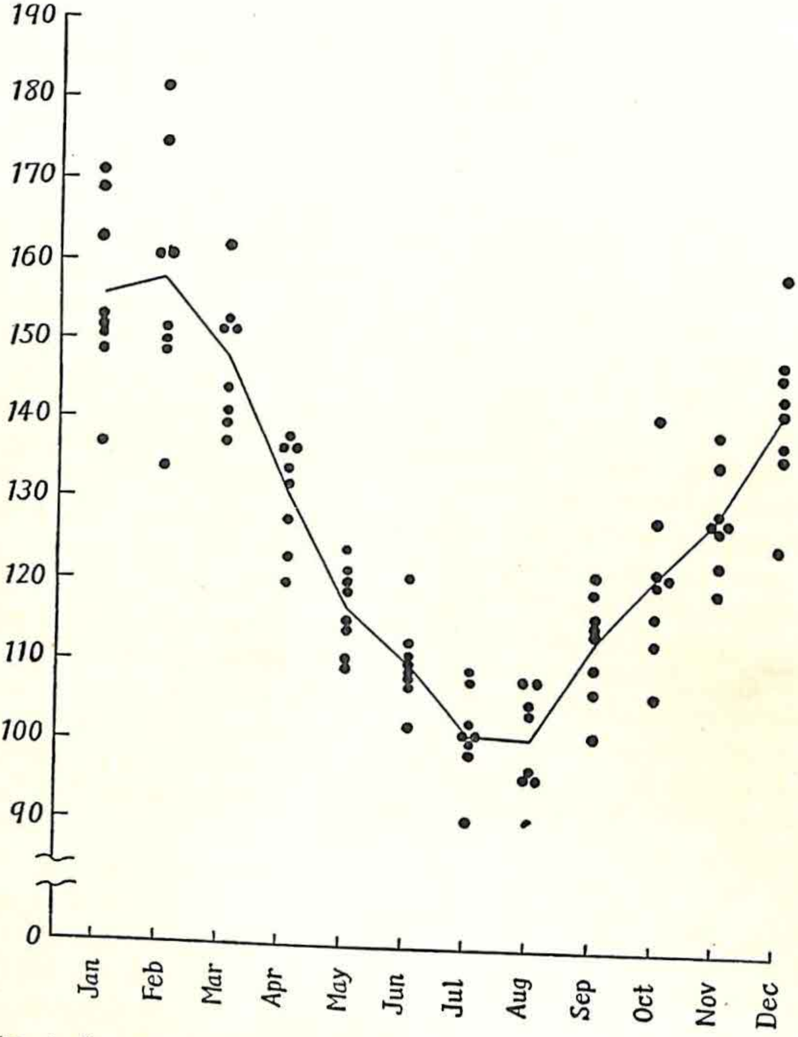

FIG. 4. SEASONAL VARIATION OF CEREBRAL HEMORRHAGE DEATH RATE PER 100,000 POPULATION IN JAPAN (1947-1954).

Then why is the death rate from cerebral hemorrhage and the prevalence of hypertension lower in Hokkaidō? Hokkaidō has been cultivated, mainly, only since the second half of the nineteenth century, and the manner of living of the inhabitants is more influenced by

Occidental ways than is that of those living in the other provinces of Japan. In winter, heating with iron stoves, without which man can scarcely live through the colder season, prevails throughout this island. On the other hand, in the main island, even in the northeast, heating with iron stoves does not always prevail as in Hokkaidō, and the construction of houses is rather protective against the heat of summer as is usual in most of Japan. Therefore, people in Hokkaidō pass the winter in a warmer in-door environment than do those on the main island; in winter travellers from Hokkaidō to the main island are sometimes more sensitive to cold in the room than are the people who live there.

In Aomori Prefecture, which is at the north end of the main island, and in neighboring Hokkaidō, heating with iron stoves in which firewood is used began earlier and spread more widely than in the other prefectures in the northeast. The death rate from cerebral hemorrhage and the prevalence of hypertension in Aomori Prefecture is lower than in the neighboring prefectures. In Aomori Prefecture, also, in villages where the heating is more general and earlier, the average blood pressure is lower than in the other villages.

Atmospheric warmth in winter has been recorded by the self-registering thermometer in the sitting rooms of farm-houses with iron stoves and those with only a floor hearth without chimney (figure 5). Firewood is the common fuel for both stove and floor hearth. But the farm-house without stove and with only a floor hearth, which is general in the older style farm-houses in Japan, except in Hokkaidō, usually has no ceiling in the sitting room so as to avoid much of the toxicity of carbon monoxide and smoke even though there is no chimney. Therefore, only radiation is effective in warming the body of the dweller, and the atmospheric temperature in the room is more influenced by the out-door temperature. The temperature of the room almost always remains under 10° C in winter and often drops below 0° C, even in the daytime, as shown in figure 5. On the other hand, in a room with an iron stove the in-door temperature is almost always kept above 20° C except at night.

Subjects aged 40–69 in farm-villages in Aomori and Akita prefectures whose blood pressures were measured by Riva-Rocci's mercury sphygmomanometer in summer, were divided into two groups: one group (A) had iron stoves in their sitting rooms and the other (B) had floor hearths only. The difference in average systolic blood pressure between these two groups is significant at the level of $P < 0.001$ by χ^2 test, as shown in table 7. The relation of temperature in the room and blood pressure is higher in females than in males. This may be understood from the fact that women usually stay in the home, while men work hard outdoors (which brings bodily warmth) or are likely to be in well-heated offices or public structures.

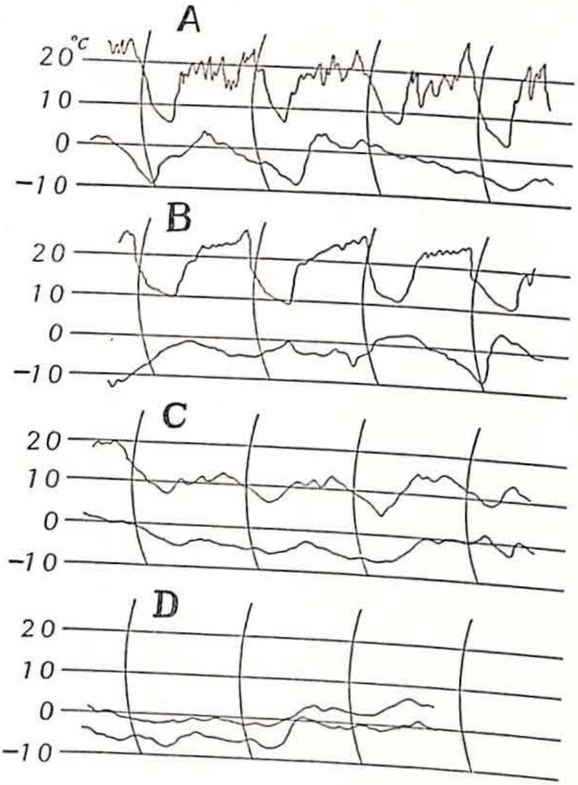

FIG. 5. THERMOGRAM OF ATMOSPHERIC TEMPERATURE IN THE SITTING ROOM WITH AND WITHOUT HEATING.

A: With stove of iron, in wooden-house.

B: With stove of iron, in concrete-block-house.

C: With *pechka*, in wooden-house.

D: With floor-hearth only, in wooden house.

The upper line shows the atmospheric temperature in the room, the lower line shows the out-door atmospheric temperature at the same time. A and D are the most usual winter patterns in the northeast farm-villages.

Lower blood pressure occurs especially in farmers who have had heating by stove in their sitting-room for over 5 years. Possession of heating in rooms seems related to the economic condition of farmers.

TABLE 7

Difference in the incidence of hypertension of farmers with and without stoves in their houses in Aomori and Akita Prefectures

MALE

Group	Number of Hypertensives	Number of Normotensives	Total
With stove	93	148	241
Without stove	59	63	122
Total	152	211	363

$\chi^2 = 3.174, \quad 0.05 < P < 0.10$

FEMALE

Group	Number of Hypertensives	Number of Normotensives	Total
With stove	140	190	330
Without stove	98	74	172
Total	238	264	502

$\chi^2 = 9.599, \quad P < 0.01$

Male plus female $\chi^2 = 12.542, \quad P < 0.001$

Notes: 1. Subjects are farm villagers and aged 40–69 of both sexes.
2. Hypertensives mean subjects whose systolic blood pressure showed 150 mm Hg and above.

However, when the total farm area is considered, the influence of this economic factor upon blood pressure is negligible as shown in the data in table 9.

Again, among 290 farm-villagers whose blood pressure was measured once in summer and once in winter, the elevation of average systolic blood pressure in winter is recognized to be at the level of significance of $P < 0.01$ in a group which contains 42 villagers who have only a floor hearth and 84 who have had stoves 5 years or less, as shown in table 8. On the contrary, as shown by another group which contains 164 villagers who have had stoves 6 years and longer, a significant elevation of average blood pressure in winter is not recognized ($P > 0.05$). Between these two groups, the difference in the winter to summer proportion of persons whose blood pressure is elevated 10 mm Hg or over is significant at the level of $P < 0.01$ by the χ^2 test.

TABLE 8

Average elevation of systolic blood pressure in winter compared with that in summer in the same 290 persons, grouped by possession of heating in house

GROUP	PERSONS	AVERAGE ELEVATION OF B. P. IN MM HG	STANDARD DEVIATION
With stove 6 years and longer	164	+1.4±1.5	19.0
With stove 5 years and less	84	+11.0±2.0	18.5
Without stove	42	+11.1±3.3	21.7

Note: Numbers following ± mean standard error of average elevation of B. P.

Significance of difference of blood pressure elevation between two groups

GROUP	PERSONS WHOSE B. P. ELEVATED	PERSONS WHOSE B. P. NOT ELEVATED	TOTAL
With stove 6 years and longer	71	93	164
With stove 5 years and less Without stove	78	48	126
Total	149	141	290

$\chi^2 = 9.878, \quad P < 0.01$

Note: Persons whose systolic blood pressure was 10 mm Hg or more higher in winter than in summer are listed as "elevated."

The influence upon blood pressure of microclimate in the sitting room should be considered in two ways, direct and indirect. Directly, low temperature contracts the surface arteries; indirectly, temperature influences the amount of rice and sodium chloride eaten.

The fact that cerebral hemorrhage and hypertension in Japan are high in the northeast and low in the southwest, seems to be roughly related to the in-door temperature in the sitting room.

TABLE 9

Relation of the farm area and the prevalence of hypertension (over 150 mm Hg, systolic) in farmers in the northeast farm-villages

FARM AREA FOR VEGETABLES	NUMBER OF HYPERTENSIVES	NUMBER OF NORMOTENSIVES	TOTAL
Under 20 are	122	78	200
20–40	64	64	128
40 are and over	62	88	150
Total	248	230	478

$\chi^2 = 13.46, \quad P < 0.005$

FARM AREA OF RICE FIELD	NUMBER OF HYPERTENSIVES	NUMBER OF NORMOTENSIVES	TOTAL
Under 0.5 ha	51	56	107
0.5–1.0	71	73	144
1.0–1.5	65	72	137
1.5 ha and over	39	42	81
Total	226	243	469

$\chi^2 = 0.29, \quad P > 0.90$

FARM AREA, TOTAL	NUMBER OF HYPERTENSIVES	NUMBER OF NORMOTENSIVES	TOTAL
Under 1.0 ha	77	51	128
1.0–1.5	73	63	136
1.5 ha and over	89	100	189
Total	239	214	453

$\chi^2 = 5.14, \quad 0.10 > P > 0.05$

Note: Agriculture in Japan is intensive, and the farm area is generally smaller than that in the U. S. A.

II. *On the influence of dietary customs.*

Besides the influence of atmospheric temperature, food and dietary customs seem to influence blood pressure and the death rate from cerebral hemorrhage. Keys, Henshel and Taylor ('47) found that during semi-starvation blood pressure diminishes following a drop in the body weight. Similar changes were observed during starvation in the last great war in Europe. Namely, Lups and Francke ('47) recognized in 1945 in 520 patients in Holland that blood pressure had fallen substantially. According to Brožek, Chapman and Keys ('48) after the siege was lifted in Leningrad it was found that arterial pressure increased. Also in Japan, in the period of food shortage, during and immediately after the last war, blood pressure fell (Watanabe, '54. See fig. 6). Many Japanese authors share the opinion that the drop of blood pressure recognized in insurance policy holders and in patients of the university clinic was chiefly caused by under-nourishment during and just after the war. According to government vital statistics, the crude death rate from cerebral hemorrhage, which was about 180 per 100,000 population in 1938-40, dropped one-third to about 120 in 1948-49.

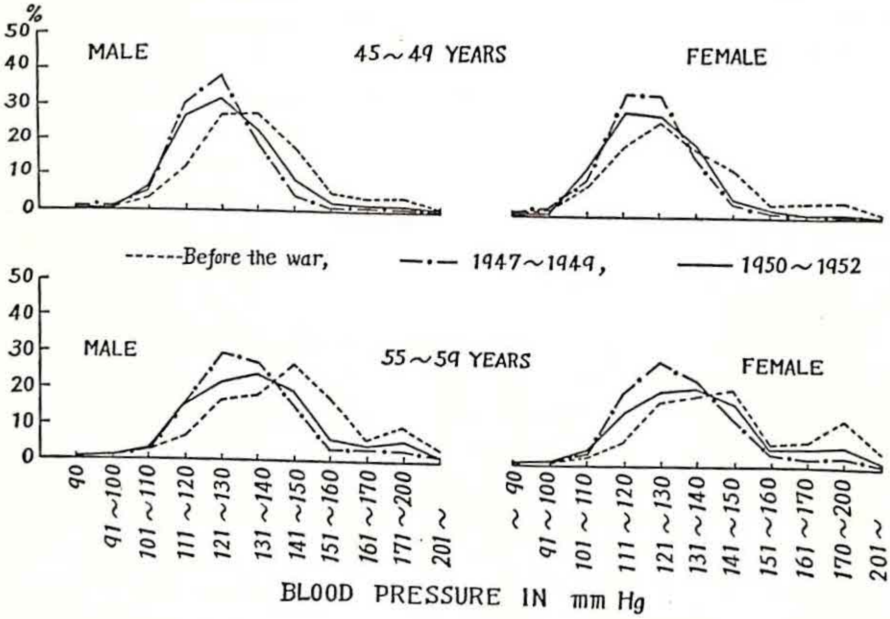

FIG. 6. COMPARISON OF PERCENTAGE DISTRIBUTION OF SYSTOLIC BLOOD PRESSURE BEFORE AND AFTER WORLD WAR II (BY WATANABE, '54).

On the influence of dietary customs, Professor Kondō ('55) of Tōhoku University, who has studied dietary customs and longevity in Japan for more than 15 years, states that: (1) the longevity index—

per cent of persons over 70 years in populations which are not rapidly increasing or decreasing—is always low in villages where inhabitants have a partiality for rice and eat over 700 g (*ca.* 2400 Cal.) of rice daily; (2) inhabitants of villages where the longevity index is high always eat enough fish, or much food processed from soy beans and many vegetables; (3) in villages where inhabitants usually eat sea weed, there are very few incidents of cerebral apoplexy and the longevity index is high, etc. Whether the longevity index of a village is high or low is influenced mainly by the incidence of cerebral hemorrhage in the middle age class. Significant negative correlation (male, $r = -0.81$, $P < 0.001$; female, $r = -0.77$, $P < 0.001$) is found between longevity index and middle age death rate from cerebral hemorrhage in 38 prefectures, not in 8 prefectures containing big cities or industrial districts which have a different age-sex distribution of population from others (Takeda, '56).

In Occidental countries, high protein diet seems generally to be one of the causes of hypertension, though Dublin, Fisk and Kope ('25) found no significant difference in the percentage of hypertension in those taking a high protein diet and those who did not. Recently, in Occidental countries, a rice diet is sometimes used for the treatment of hypertension. The quantity is always limited to about 2,000 Calories, however, and is accompanied with a severe restriction of sodium chloride.

In Japan, especially in farm-villages in the single crop area, where farmers have comparatively large rice fields (*ca.* 1-2 hectare) but smaller fields for vegetables (*ca.* 2-3 are), which are usually for home consumption only, farmers tend to overeat rice, with only small side dishes, generally of thick salted pickles. According to the results of the government national nourishment survey, adult farm-villagers of all provinces take an average of *ca.* 2,500 Cal. of which 55-65% is in rice. Takahashi *et al.* ('54) found that in the customary diet in farm-villages in a single rice crop area of Aomori Prefecture, where the country is covered with drifted snow during three or four months in winter, 70-80% of the calories of all foods (*ca.* 3000 cal.) are from polished rice and that in the period from March through May, it often exceeded 80%. Polished rice is lacking in vitamins. Therefore, the larger the amount of rice they eat, the more they lack in vitamins, and latent polyavitaminosis is found very often in the farm villages. We found the customary diet lacking adequate vitamin B_1, B_2, C, etc. and also calcium and fat. Farmers who have fields too small for vegetables lack vegetables, especially during winter and spring, since they do not buy them, and eat much rice with thick salted pickles.

In the northeast, the larger the vegetable fields—vegetables are mostly for home consumption—the less the prevalence rate of hypertension (Itō, '56). As shown in table 9, when 478 farmers are divided into three groups according to the extent of farm area used for vegetables, the differences of prevalence rate among these three groups are statistically significant by the χ^2 test at the level of $P < 0.005$. On the other hand, there is no significant relation between the area of rice fields and the proportion of hypertensives. Although agricultural labor is heavier in the rice fields than in the fields for vegetables, it seems probable that physical exertion is not an important factor in the genesis of essential hypertension (Pickering, '55).

We find there is a significant positive correlation between estimated production of rice (average for 1942-50) per capita (both estimated production and population are cited from the government Statistical Yearbook, 1950) and the middle age death rate from cerebral hemorrhage (male, $r = +0.602$, $P < 0.001$; female, $r = +0.552$, $P < 0.001$) in 42 prefectures (except Tōkyō, Kanagawa, Ōsaka and Kyōto prefectures, which have small farm areas as against large urban populations). It follows, under the premise that inhabitants in prefectures where more rice is produced eat more of it, that, in Japan, the people who eat more rice have a higher incidence of cerebral hemorrhage. The low death rate from cerebral hemorrhage in Hokkaidō is explained by the low productivity of rice resulting from the climate, in addition to the above-mentioned influence of higher indoor temperatures in winter.

Ogata *et al.* ('54) state after their experiments on the influence of a large amount of sodium chloride ingestion in North Manchuria as follows: "Daily intake of sodium chloride amounting to 50–60 g by adding 10 g to each meal causes a gradual rise in basal metabolism, good appetite, and energetic feeling of the body, after several days. In this stage of high metabolic rate due to increase of salt ingestion, both a rise in the oxygen consumption and a drop in the surface temperature during exposure to cold are less in degree and the subjects complain less than normal subjects." Though the observation was not continued for so long a period, it seems that it would be good to take more sodium chloride in colder environments. However, at the same time, it is well known that overdosages of sodium chloride in daily life produce hypertension: *e.g.*, Dahl and Love ('54) state that no hypertension was found among a low sodium chloride intake group, but a high intake group had hypertension in 10% of the subjects. Sasaki ('56a) has shown that the soy bean paste, "miso," from which the soup is made which almost all Japanese eat every day (farmers eat it always, at each meal) contains more sodium chloride in the north than in the south of Japan and that there is significant positive correlation ($r = +0.49$, $P < 0.01$) between the sodium chloride content of the paste and the middle age death rate from cerebral hemorrhage in 36 prefectures.

Sasaki ('56b) investigated the quantities of sodium and potassium (by flame photometer), chlorine and creatinine in the urine of 97 farm housewives, aged 31–64 years, in farm villages: village A in Aomori prefecture and B in Akita prefecture. Village A is in the area of apple production and all subjects (41) have iron stoves for heating in their sitting room: 32 of them have had stoves for over 10 years. Of the subjects of village B (56), only 7 have had iron stoves for over 10 years, and 24 still lack stoves. There proved to be no difference in upper-arm circumference between these two groups of farm-housewives, and, as this is the simplest and most definite way to compare physical build of different groups as it relates to blood pressure (Bays and Scrimshaw, '53), body build does not appear to be a factor, here. But there is a significant difference of average blood pressure, both in systolic (in village A: 132.1±2.6, in B: 171.8±4.8 in mm Hg; the number following ± being the standard error) and in diastolic (in A: 78.4±1.8, in B: 90.4±2.2 in mm Hg), and of percentage of hypertension, between these two groups. In the urine, there were remarkable differences in the ratio of Na/creatinine and of Na/K between group A:

[Na(m. Eq.)/Cr.(g): 242.1±18.9; Na(m. Eq.)/K(m. Eq.): 4.72±0.38]

and group B:

[Na(m. Eq.)/Cr.(g): 383.0±23.1; Na(m. Eq.)/K(m. Eq.): 7.14±0.60].

It seems that one should take more sodium chloride in a cold environment, such as in the rooms which have no heating during winter except the floor-hearth.

Irie ('53) found a decrease in vitamin C concentration in blood serum after 4–5 days of adding 20 g NaCl to the ordinary diet; this is in accordance with the results of animal experiments by Doi ('53).

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In farm-villages in the northeast of Japan, it seems farmers lack vitamin C doubly, not only in their food but also by excessive intake of sodium chloride. In fact, Matsuoka *et al.* ('51), Fukuda *et al.* ('52), Okumura ('55), and Sasaki, Takeda and Itō ('55) have found low blood levels of vitamin C especially in the season of snow-drifts in this province.

Anyhow, excess intake of rice and salt and lack of vitamin C and other vitamins seems to be one of the important causes why, in the northeast, the average blood pressure is elevated and the death rate from cerebral hemorrhage is high. Excess intake of rice, especially, seems to influence the geographic distribution of cerebral hemorrhage in Japan.

III. *On the influence of psychogenic factors and of social environment.*

On the influences of psychogenic factors and of social environment upon cerebral hemorrhage and hypertension we have no appreciable data in Japan. It is said that the inhabitants of coast villages, especially fishing villages, tend to be extroverts in personality in comparison with the inhabitants of inland villages where they seem to be introverts. The inhabitants of such fishing villages usually seems to have lower mean blood pressure, lower prevalence of hypertension and a lower death rate from cerebral hemorrhage than those of inland and mountain farm-villages. But we have no certain evidence on the relation of personality and blood pressure.

In table 10, which shows death rates from chief causes by occupation, we find higher death rates from cerebral hemorrhage in occupation classes of other professional workers and farmers, farm workers, and graziers, in which cerebral hemorrhage is the most important cause of deaths, though the death rates are not corrected for age and sex. As for farmers and related workers, who are the greater part of the population of Japan, we can interpret the geographic distribution of cerebral hemorrhage and hypertension by atmospheric temperature and dietary customs, as mentioned above. Other professional workers seem to contain more urban inhabitants. The fact is generally recognized that "the blood pressure cuff reveals higher values in complex societies than in simpler social environments," as Bays and Scrimshaw ('53) put it. That other professional workers have the highest death rate from cerebral hemorrhage seems mostly explained by that idea, even though they seem to contain the older generation.

TABLE 10

Death rates from chief causes by occupation in Japan, 1951-1952
(from Mortality Statistics by Occupation and Industry, 1955)

CHIEF CAUSES OCCUPATION		TUBERCULOSIS	MALIGNANT NEOPLASMS	CEREBRAL HEMORRHAGE	HEART DISEASES	ACCIDENTS
Professional and technical workers	Technical workers	*135.6*	63.8	54.7	36.6	63.8
	Professors and teachers	*112.5*	39.8	35.9	22.6	16.0
	Other professional workers	167.5	147.6	*187.6*	101.2	36.2
Managers and officials		91.4	*105.7*	104.1	54.5	31.3
Clerical and related workers		*150.7*	54.6	43.9	34.6	30.5
Sales workers		*120.8*	105.0	116.3	71.3	39.0
Farmers, farm workers, and graziers		77.1	114.0	*153.3*	25.9	38.0
Lumbermen, hunters, and related workers		43.7	29.4	43.4	25.5	*156.3*
Fishermen and related workers		87.3	83.8	69.9	49.2	*103.4*
Workers in mines and quarries		130.0	60.0	47.3	35.7	*315.1*
Workers in transportation		101.4	39.1	30.3	25.1	*149.4*
Workers in metals		*131.2*	51.1	38.4	35.2	59.4
Workers in textiles		*105.7*	71.9	61.9	52.8	35.7
Workers in fabricated textiles		*177.2*	45.6	60.8	49.4	21.5
Workers in wood and wood products		*97.7*	74.3	74.8	47.1	49.0
Machinery operators and related workers		68.1	34.1	33.0	23.1	*83.5*
Other craftsmen		*102.8*	56.0	57.8	40.4	66.8
Laborers (except farm, mine, and services)		93.5	56.8	61.4	45.9	*122.0*
Protective service workers		*149.1*	44.2	34.5	26.4	40.3

Note: Italic death rate numbers mean the most significant causes of deaths for each occupation.

However, higher death rate from cerebral hemorrhage and higher mean blood pressure in the northeast of Japan compared with the southwest is not explained by social environment, since in Japan it is common knowledge that inhabitants in the northeast are regarded as having a less complex society and a less elaborate culture than in the southwest.

SUMMARY

In Japan the incidence of fatal cerebral hemorrhage among the middle aged is higher in the northeast, except in Hokkaidō, than in the southwest. The distribution of the mean blood pressure, the prevalence of hypertension and the proportion of low blood pressure seem parallel to the distribution of the death rate from cerebral hemorrhage, though we are lacking in data from local mass surveys for some parts of Japan.

This geographic distribution of cerebral hemorrhage and hypertension seems explained in part by the differences of atmospheric temperature. One must consider not only natural, out-door temperature but also in-door temperature which, especially in winter in the north of Japan, is more effectively influential upon the human body. Areas where cerebral hemorrhage and hypertension are frequent in farm villages also seem to be those in which there is a surplus intake of rice and salt, and a lack of vegetables.

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THE RELATIONSHIP BETWEEN PHYSIQUE AND RATE OF SKELETAL MATURATION IN BOYS

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IN a recent analysis of the Brush Foundation Growth Study material, Dupertuis and Michael ('53) compared the growth pattern of two groups of boys with different physiques. It was found that those who were predominantly of a rugged, muscular build (Sheldon's second component) grew more rapidly than those whose physique was more finely and delicately constructed (Sheldon's third component), but that the latter group were, on average, taller as adults. This finding is consistent with Shuttleworth's ('37, '38) observation that slow physical maturation during adolescence is associated with greater than average adult height, and rapid maturation during the same period with shortness of stature. Acheson and Hewitt ('54) found that, in the pre-school period, the group of children of either sex which reached a given stage in their skeletal maturation late were taller at that stage than the group of children who reached the same stage early; this suggested that the inverse relationship between adult stature and rate of physical maturation might be a basic, constitutional pattern which is genetically determined and is detectable from early childhood. What is more, it seemed highly probable that there would be a basic relationship between Sheldon's somatotypes and the rate of physical maturation—either skeletal or sexual. The present paper investigates the validity of this hypothesis in respect of the same group of boys as were used in the earlier paper (Dupertuis and Michael, '53).

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MATERIAL AND METHODS

Material

Full details of recruitment and conduct of the Brush Foundation Study have been published elsewhere (Simmons, '44). The children who provided the longitudinal data were all born after the first World War, and the majority of them were followed between 1931 and 1942. They were specially selected from prosperous homes with the idea that this would permit the study of child development under optimum conditions. At the time that recruiting was going on it was widely believed that obesity in childhood was an indication of pituitary insufficiency, and therefore, although children who tended to be fat were followed, their records were not filed among the normal or "regular" series. In 1951, when a circular letter was sent to the 250 boys whose records were the most complete, asking them to return for a final assay of adult physique, this fact was not realized. Consequently, among the 128 who eventually presented themselves at this laboratory there is an artificially small amount of Sheldon's first component (roundness and fatness).

Somatotyping

The 128 boys whose physiques were classified had all reached young adulthood. The classification was made by the classical method of Sheldon (Sheldon, Stevens, and Tucker, '40; Sheldon, Dupertuis, and MacDermott, '54) from standard photographs of the naked individual.

Assessment of Skeletal Maturation

Skeletal maturity was assessed from x-rays of the hip and pelvis by the Oxford method[2] (Acheson, '54, '56, '57). This part of the body was chosen for no other reason than that its maturation had already been assessed in a separate study (Acheson, '57), and that maturity readings were thus available for a total of 225 Brush boys, including the 128 who had been somatotyped. The mean maturity scores, together with standard deviation for this entire group, are shown in table 1.

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[2] This method depends upon the recognition of shape changes in the parts of the maturing skeleton where osteogenesis is occurring. Those shape changes which are neither sex-limited nor stock-limited are described as maturity indicators, and the total number of these indicators in any x-ray film is known as the maturity score, which is taken as an index of the maturity of the whole skeleton. In the first report of this method (Acheson, '54) the scores were described as Oxford Units. It has since been realized that the various contributions to the total maturity score are not necessarily equal to each other, and so it is incorrect to describe them as units. In the present communication they will be referred to as maturity points.

TABLE 1

Mean maturity score in points for the hip and pelvis of 225 Brush Foundation Study boys, assessed by the Oxford Method from 2,505 radiographs

(The maximum score, attained by the mature individual, is 45 points.)

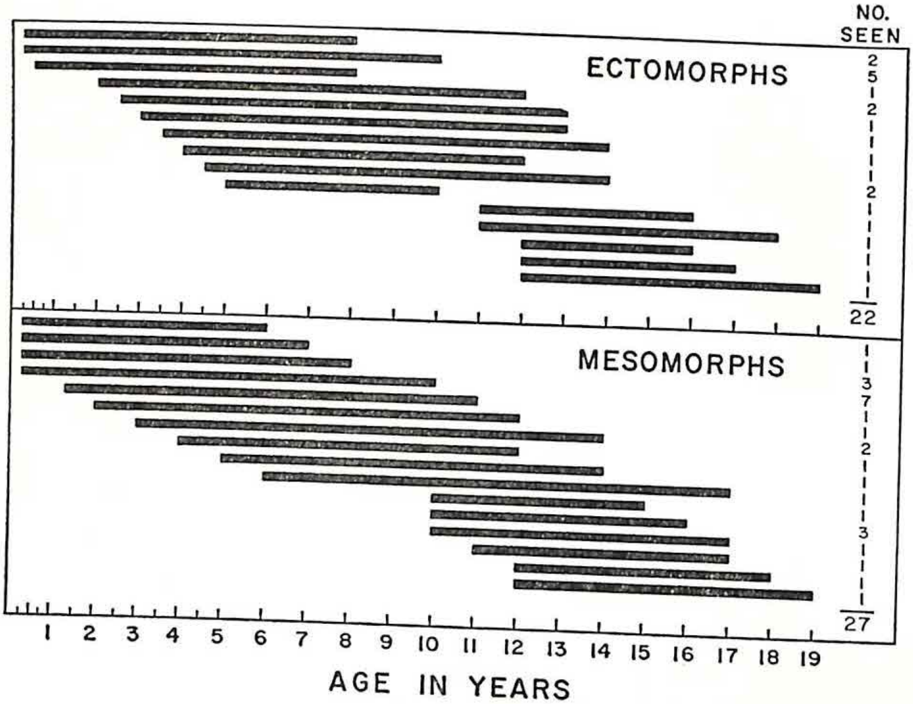
AGE IN YEARS	MATURITY SCORE IN POINTS MEAN	STANDARD DEVIATON	NUMBER OF OBSERVATIONS
¼	4.45	1.01	53
½	6.31	1.06	61
¾	7.71	0.87	70
1	8.37	0.82	78
1½	9.34	0.85	88
2	10.11	0.89	96
2½	11.14	1.10	104
3	12.05	1.26	108
3½	12.94	1.30	111
4	13.98	1.33	126
4½	14.98	1.47	128
5	15.97	1.42	139
6	17.25	1.43	150
7	18.39	1.40	149
8	19.57	1.35	149
9	20.71	1.32	138
10	21.90	1.52	145
11	23.35	1.73	116
12	24.98	2.06	114
13	26.85	2.38	102
14	29.72	2.61	86
15	32.56	3.28	72
16	36.13	3.96	60
17	39.54	3.17	41
18	40.95	3.15	21
Total			2,505

None of the boys who were somatotyped had been studied for more than 11 years, and very few of them for less than 5. The actual ages at which some of them were seen are indicated in table 2. The maximum number of x-rays available for any child was 18.

The following procedure was adopted in order to obtain an index scale of the rate of maturation for each child. From the maturity score of each x-ray, the mean maturity score of those members of the entire group of 225 boys who were seen at the same age was subtracted. Then this difference, in maturity points, was divided by the standard deviation of the scores of all the boys at that age and multiplied by 100.

TABLE 2

A diagrammatic presentation of the time span during which the 22 ectomorphs and 27 mesomorphs were followed. With very few exceptions each child was seen every three months in the first year of life, twice yearly until he was 5, and then annually. These cases are typical, in this respect, of the Brush Foundation data.



Thus the differences were transposed into standard units. Then, for each child, all these differences were averaged, paying due attention to whether they were plus or minus, and the final figure was taken as an index of the rate of skeletal maturation of that child. It was realized that this would be a good index only in those children in whom the rate of maturation bore a constant relationship to the mean rate of maturation for all the boys. Since knowledge of individual rates of maturation is so meager, however, it was decided that this relatively simple index was preferable to the more elaborate method of trying to fit curves to the maturational pattern of each child.

FINDINGS

Overall Relationship between Physique and Rate of Skeletal Maturation

The fact that there is a wide normal range in the rate of skeletal maturation in boys of the Brush group has been demonstrated by Pyle and Hoerr ('55). In order to obtain a broad picture of any differences in physique that there may be between the slow maturing and quick maturing boys, the present study group was divided, in terms of the rate of maturation index, into four subgroups (see table 3). It will be seen that somatotype Component II (ruggedness) is higher among the fast maturers, and Component III (delicacy and linearity) is higher among the slow maturers. There is also the suggestion of a gradient for Component I, with even less roundness and softness among the slow maturing group than among the boys who are skeletally more precocious. The findings are strikingly similar to those of Tanner ('55), who compared somatotype components with rate of sexual maturation, judged by first appearance of pubic hair, in a group of 188 British officer cadets. Tanner found, however, that the relationships between somatotype Component II and fast maturation and between Component III

TABLE 3

Average somatotype components in four groups of Brush boys, arranged according to rate of skeletal maturation

	RATE OF MATURATION SCALE (IN STANDARD UNITS)			
	SLOW		FAST	
	—100 or less	—99 to 0	0.1 to 100	101 or greater
Component I (Endomorphy)	3.30	3.36	3.40	3.60
Component II (Mesomorphy)	4.07	4.11	4.15	4.45
Component III (Ectomorphy)	3.87	3.46	3.16	3.05
Number of Observations	(15)	(60)	(43)	(10)

and slow maturation were both statistically significant. In the present data only the linear regression of Component III and rate of skeletal maturation differed significantly from zero ($.01 < P < .05$). Tanner's subjects, in whom Component I averages lower than in ours, showed no consistent trend in respect of this component.

In addition to considering the physique of the boys in relationship to their rate of maturation, partial linear regressions were calculated for the rates of maturation associated with the three somatotype components. For all three combined, no significant relationship was detected; however on further analysis ectomorphy was found to have a relationship with slow maturation ($.01 < P < .05$).

Rate of Skeletal Maturation

1. Preponderance of Components II and III. In order to examine the developmental patterns of boys showing a high degree of Components II and III, the same group of 22 boys with more than 5.0 in Component III were studied as had been used in the previous analysis (Dupertuis and Michael, '53). Two of the 27 mesomorphs were not 18 years of age and therefore not quite fully grown when last seen, so that only 25 boys with more than 5 in Component II were available. A scattergram was made (figure 1) in which rate of maturation was plotted against final adult height for the two groups. This shows a highly significant tendency for boys with a delicate and linear physique (Component III) to be slower maturing and taller ($\chi^2_{(2)} = 11.68$, $.001 < P < .01$) than boys with a predominance of Component II.

2. Gynandromorphy. Gynandromorphy was estimated in all the boys by the method of Sheldon ('40), but it was found that only 9 had a rating of over 3.0 in this component. Thus we are unable to affirm or to refute Bayley's ('51) statement that boys who are gynic in their physical build mature more quickly than average.

The Relationship between Physique and Pattern of Skeletal Maturation

It is half a century since Pryor ('08) pointed out that the pattern of ossification in children varies considerably. He believed that this variation was entirely due to genetic differences. Subsequently, Pryor himself ('39), Buschke ('34), Sontag and Lipford ('43), and other authors have produced good evidence in favor of the suggestion that variations in pattern have a genetic basis. Todd ('37), however, con-

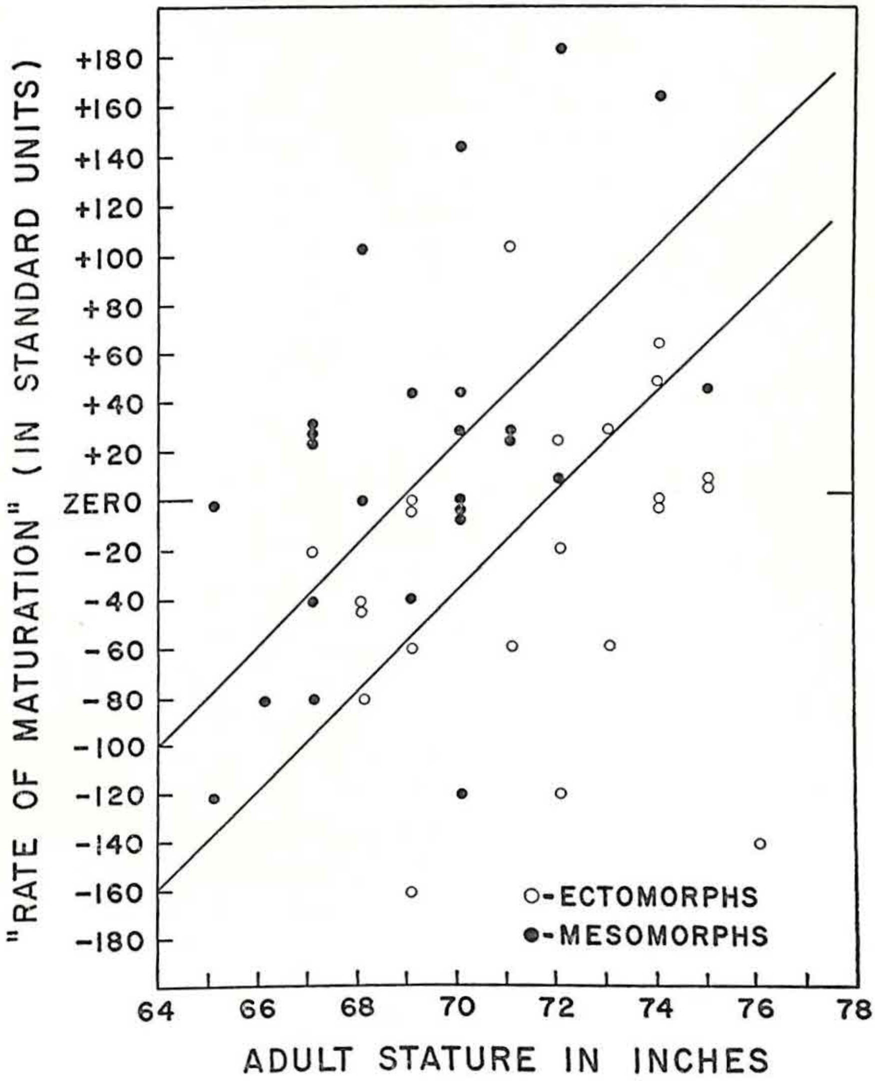


Fig. 1. A Scattergram Showing the Adult Stature against Rate of Skeletal Maturation of 22 Boys with a Rating of 5 or Above in Component III and 25 Boys with 5 or Above in Component II.

tended that illness or malnutrition could also disturb the pattern of ossification. The use of the Red Graph by Pyle and her co-workers ('48) in a group of children in Michigan and also in Birmingham, Alabama (reported by Driezen, Snodgrasse, Parker, Currie, and Spies, '54), has borne out Todd's contention. Subsequently, further support came from Hewitt, Westropp, and Acheson ('55), who showed that the maturation of the carpals was more susceptible to interference from the intercurrent illnesses of childhood than the maturation of the epiphyses of the short or the long bones in the wrist or the knee. Thus, it seemed that both heredity and environment each play their part in determining the pattern of skeletal maturation in children.

We have already shown that there is some relationship between physique and rate of maturation, and the question arises as to whether the pattern of skeletal maturation might also have some association with physique. That is to ask, whether the slower rate of maturation associated with ectomorphy reflects a general and equal slowing of the development of all ossific centers, or whether a differential effect can be detected between one type of center and another? In order to study this question further, a detailed comparison was made between three different types of center in the predominant mesomorphs and the predominant ectomorphs. The remaining 79 boys who were not predominant in either component served as controls. The centers chosen for study were:

1. Articular epiphysis—Head of femur
2. Traction epiphysis—Greater trochanter
3. Primary center—Junction of pubic and ischial rami.

Each of these provided a single maturity indicator series, and the stages observed are illustrated in figure 2.

The comparisons were made both by estimating the mean ages at which the various maturity stages were achieved by each group, and by plotting graphically the ages at which each of the boys showed the indicators in each of the three series. The numbers at each age were too few to apply tests of statistical significance; nevertheless the following trends appeared to be fairly consistent.

Articular epiphysis (head of femur). There was no suggestion of a difference in the mean age of first appearance of the center of ossification of the head of femur (Stage 1) among the three groups, nor was there any difference in the ranges of these means. Thereafter, through Stage 6, each of the three groups remained strikingly similar. However, whereas the mesomorphs on an average took only 36 months to pass from Stage 6 to Stage 7, the control group took 43 months and the ectomorphs 53 months. There was little suggestion of a difference in the times for each of the three groups to pass from Stage 7 to Stage 8.

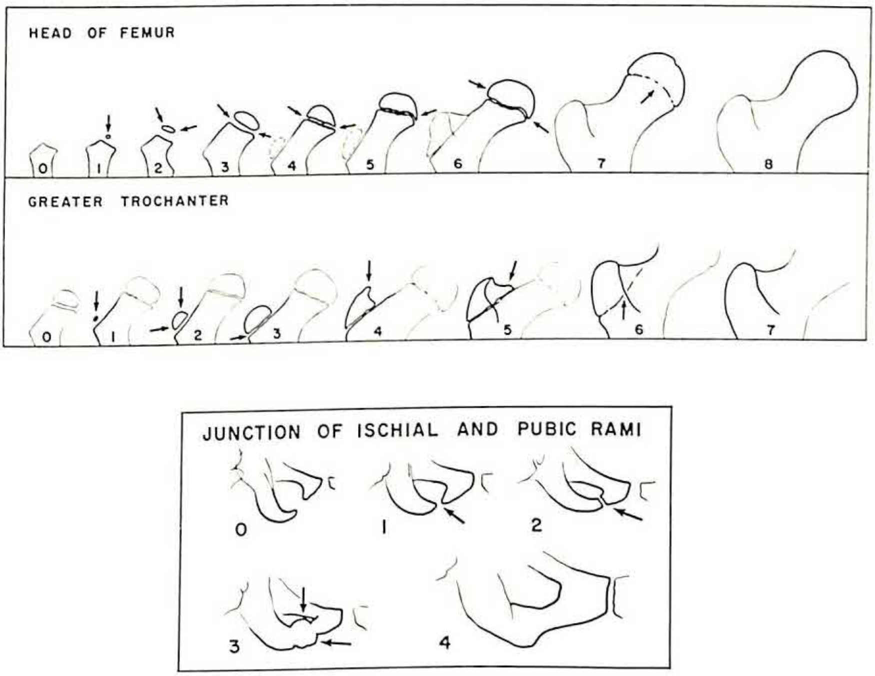
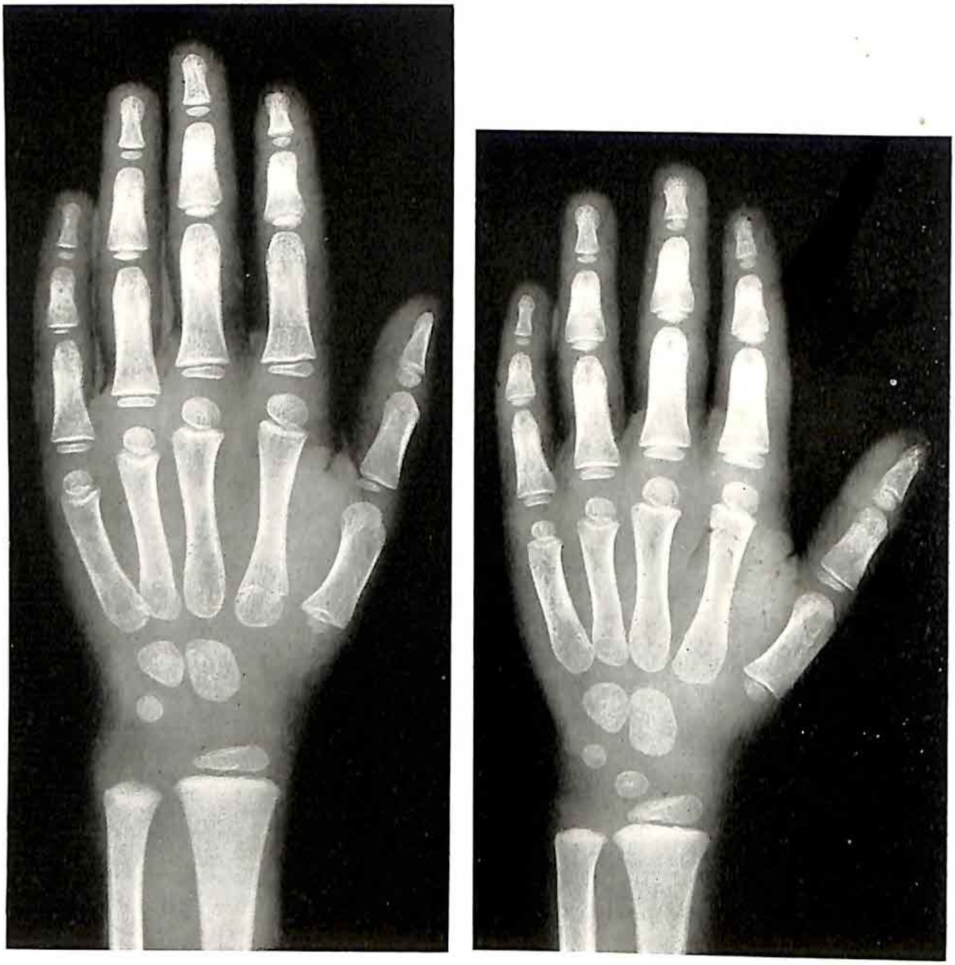


Fig. 2. Three of the 9 Series of Maturity Indicators Used in the Assessment of the Hip and Pelvis. The Time Taken for a Boy to Pass through Some of the Stages Seems to Depend Partially Upon His Physique. (See text.)

It seemed that *within* each of the three groups there was variation in rate, but in broad terms the fast and slow maturers followed channels which were more or less parallel to each other. When the groups were contrasted, however, this was no longer true. Although the ages of first appearance of ossification and the attainment of Stage 6 were similar in each group, the prolongation of the time taken to pass from Stage 6 to 7 in ectomorphs, and the reduction of this time in meso-

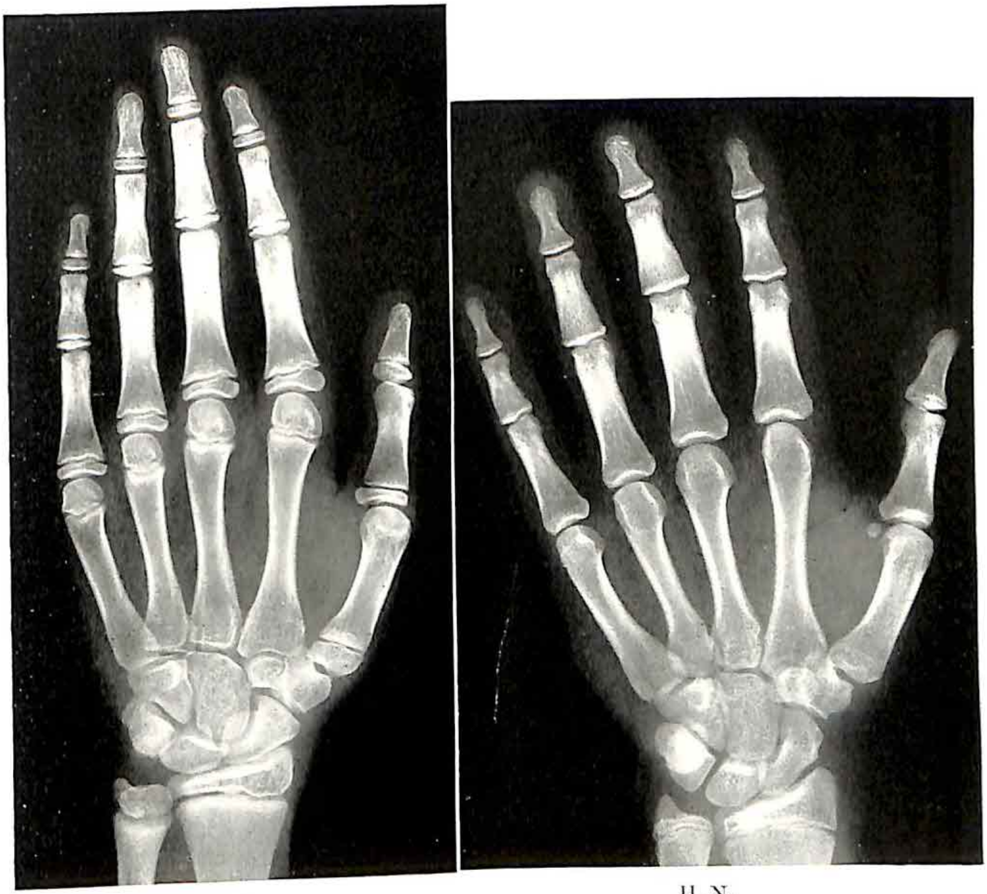


E. G.

H. N.

Plate I. Radiographs of the Hands of Two 5-Year-Old Boys. E. G. had a Somatotype of 117 and was the Most Ectomorphic Boy in the Group. H. N., with a Somatotype of 261, was the most Mesomorphic. Note that there is No Difference in the Skeletal Maturity of the Short Bones of the Hand, or of the Radius. However, the Carpals of the Mesomorph are Distinctly More Advanced.

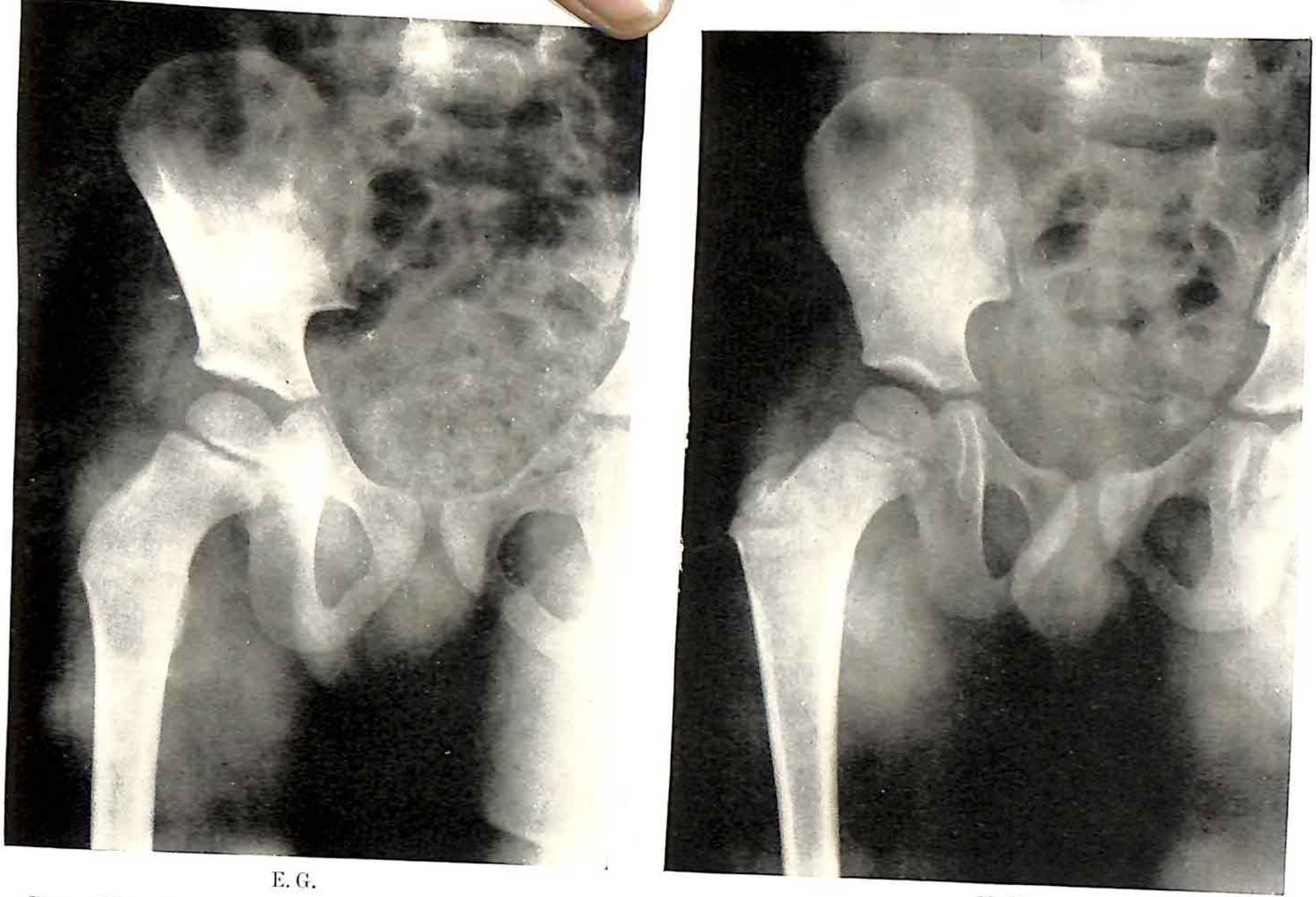
Maturity scores by the Oxford Method (uncorrected) for these hands are:
E. G., 29 points H. N., 31 points



E. G. H. N.

Plate II. Radiographs of the Hands of E. G. and H. N. at 14 Years of Age. Note that While E. G. Shows No Signs of Epiphyseal Closure, the Phalanges, Metacarpals, and Carpals of H. N. are Mature in this Respect. The Delicate Linear Bones of the Ectomorph are in Striking Contrast to the Comparatively Square, Squat Bones of the Mesomorph. No Standards are Yet Available for Assessment of Hand Radiographs at This Age by the Oxford Method.

The adult height of E. G., the ectomorph, is 190.5 cm (75 inches) and of H. N., 172.1 cm (67.5 inches).



E. G.

H. N.

Plate III. Radiographs of Hip-Joint and Pelvis of E. G. and H. N. at the Age of 5 Years. There is Little Difference in the Skeletal Maturity of the Head of Femur (Stage 4), and the Region of Acetabulum and Triradiate Cartilage; in Both Films the Junction of Pubic and Ischial Rami is at Stage 3. However, the Mesomorph Shows a Considerable Amount of Ossification in the Greater Trochanter (Stage 2), Whereas this Center Does Not Yet Show in the Ectomorph. These Two Cases are Fairly Typical of the Ectomorphs and Mesomorphs Studied

The maturity score of the two films is: E. G. 16 points H. N. 18 points.

morphs, meant that the total time elapsing between first appearance and final fusion of the epiphysis was longer in the ectomorphs. But this difference could not be predicted by inspection of the center on the radiograph for Stages 1 through 6.

Inspection of the hand films of the same boys suggested that what is true for the head of the femur may also be true for the epiphyses of the short bones of the hand. Plate I shows the hand of the most ectomorphic boy in the study (somatotype 117) compared with that of the most mesomorphic (somatotype 261) at the age of 5 years. There is no detectable difference between the maturity status of any of the epiphyses in the fingers or the wrist. However, when the same two boys had reached the age of 14 years, all of the epiphyses were already united in the hand of the mesomorph, whereas those of the ectomorph had not yet exhibited any suggestion of union (plate II). In plate III, the hip joints of the same boys are shown, and it will be noted that the head of the femur is equally mature (Stage 4) in both.

Traction epiphysis (greater trochanter). The greatest difference between mesomorphs and ectomorphs with respect to the greater trochanter was the time of first appearance of ossification. The average age at which ossification was first seen in the mesomorphs was 46 months and in the ectomorphs 51 months. The figure for the control group was also 46 months (Francis and Werle, '39, found that 74% of the Brush boys they studied had this center ossified by the age of four years); hence, the suggestion here is that appearance in the ectomorphs is delayed. However, by the time the three groups had reached Stage 3, the ectomorphs appeared to have caught up, and the mean ages and range of variation at which Stages 3 through 5 were achieved were strikingly similar. There was a suggestion that final fusion may occur a little earlier in the mesomorph. Delay of appearance of this center in an ectomorph is well shown in plate III, where there is no sign of ossification at the age of 5 years, whereas the mesomorph has already reached Stage 2 at the same age.

Primary center (fusion of ischial and pubic rami). It was in the fusion of ischial and pubic rami alone that a steady and parallel difference was maintained among the three groups throughout the maturation process. The mean age for reaching Stage 1 was 34 months for the mesomorphs, 46 months for the ectomorphs, and 41 months for the controls; and the ages for final maturity (Stage 4) in this indicator series were 110 months, 120 months, and 116 months respectively. The fusion of these two rami has no exact parallel in the hand, but it does represent ossification in a primary center. It therefore is interesting that ossification in the carpal bones of the mesomorphs seemed to be, on an average, slightly ahead of that of the ectomorphs. Such a difference can be seen in plate I.

The material is not suitable for any trends to be sought in boys who are predominant in endomorphy. However, when Robinow ('42) subjected the age-order of appearance of the centers of ossification to factor analysis, he found that there were three factors. The first he identified with the round bones, the second with the articular epiphyses, whereas the third he was unable to name. It is not impossible that these factors may be identified with Sheldon's three components. Nevertheless, it is important to realise that the trends we have described were slight, and that the analysis of more comprehensive data may show them to be false.

Rate of Skeletal and Sexual Maturation in Boys Who Are Very Obese, as Reported in the Literature

In the Oxford Child Health Survey studies were made of minor changes in rate of growth in stature, and in rate of skeletal maturation (Acheson and Hewitt, '54; Hewitt, Westropp, and Acheson, '55). It was suggested that if the genetically endowed "growth potential" of a child is accepted as the maximum number of units it can add to its stature for each unit gain in maturity, then at any time when the child's rate of growth is slowed more than its rate of maturation, it fails to fulfill its growth potential. It was shown that poor home circumstances, and even minor illnesses, can interfere with the fulfillment of this growth potential. Wolff ('55) reported observations on a group of 100 children who attended a pediatric clinic in Birmingham, England, because of obesity; in only three did he find evidence of endocrine imbalance or any other gross pathological disorder. He put many of the remainder on a slimming diet, and in those cases in whom this treatment had the desired effect of reducing weight, the rate of increase of stature was also slowed. What is more, there was a direct relationship between the amount of weight loss and the decrease in rate of linear growth. This strongly suggests that the minimum amount of food these children require to fulfill their growth potential will at the same time make them obese. Whether or not the fulfillment of growth potential in such cases is desirable, the facts suggest that the tendency to obesity in these children is constitutional, or, as Sheldon would put it, they are highly endowed with endomorphy. This conclusion is supported by Stuart ('55) who, when discussing obesity in childhood, wrote "there is a strong genetic predisposition to become obese . . . and this is commonly, though not necessarily, associated with such characteristics as being tall for age. . . ."

It has already been pointed out that Todd deliberately omitted obese children from the main Brush Study group. We therefore decided to examine growth data of obese children in the literature in order to try to determine the contribution of Component I to the rate and pattern of skeletal maturation in childhood. In addition to the work of Wolff ('55, '56), there are reports from Paris (Nobécourt, '37, '38), New York (Bruch, '38), and Copenhagen (Quaade, '55) in which the authors publish comprehensive anthropometric data, and conclude that endocrine imbalance is not the cause of obesity in their respective study groups; they suggest that the condition is more probably due to the constitution of the child, or to a tendency to overeat—or to both. Two hundred and twenty-eight boys were followed in these four centers, and when to these is added Stuart's case ('55), the data from 229 obese boys becomes available for analysis.

1. Skeletal Maturation. Of the four main studies, Bruch's ('38) alone makes any assay of skeletal maturation. She uses a radiograph of the hand as an index, and comparing this with Todd's ('37) standard, concludes that, on average, her obese children of both sexes are unusually fast maturers. It is pertient to point out that Todd's standards were drawn from the same population as our present study group, and that they represented the mean rate of maturation for all Brush children examined up to 1935. Therefore, it is probably legitimate to conclude that Bruch's endomorphic American boys showed a faster rate of skeletal maturation than our own relatively endopenic group of American boys, this despite the fact that the New York children came from a much lower economic stratum than the Cleveland children.

2. Sexual Maturation. It has been shown repeatedly (Flory, '36, Shuttleworth, '38, Buehl and Pyle, '42, Tanner, '55, etc.) that skeletal and sexual maturation are intimately related. Therefore, since precise details of the time of appearance of the pubic hair are available in all four groups, the rate of skeletal maturation can be deduced by estimating the age of onset of puberty. In presenting their data, Nobécourt ('38) and Quaade ('55) use as controls children they themselves have observed in the cities where they practice. Wolff's ('55, '56) controls also come from the same city as his study groups, but were seen, not by himself, but by Hogben, Waterhouse, and Hogben ('48) and their co-workers. Bruch ('38) used no control group in her discussion of sexual maturation.

TABLE 4

The percentage age-incidence of appearance of pubic hair in 159 obese boys (reported in the literature)

AGE	NOBÉCOURT '38		BRUCH '38		QUAADE '55		WOLFF '55, '56		
	Obese	Control	Obese	Control	Obese	Control	Obese	Control	
10-	—	—	0 (10)		9.1 (11)	0 (40)	50.0 (4)		*Age* (*years*)
11-	18.2 (11)	0 (10)	50 (4)		7.2 (14)	7.9 (63)	44.4 (9)		
12-	9.1 (11)	0 (12)	33 (9)		41.7 (12)	15.2 (59)	50.0 (10)	25	*11.9*
13-	15.3 (13)	41.7 (12)	100 (3)		46.2 (13)	53.8 (52)	100.0 (3)	50	*12.9*
14-	37.5 (8)	70.0 (10)			100.0 (1)	84.6 (52)		75	*14.0*
15-	66.7 (9)	80.0 (5)			100.0 (6)	100.0 (25)			
16-	72.7 (11)	100 (1)							
17-									
Total No. of Cases	50	50	26	0	57	291	26	664	

Figures in parentheses denote the number of observations at each age. Bruch uses no controls, and Wolff's controls are taken from a study of 664 school boys in Birmingham, England by Hogben, Waterhouse, and Hogben '48. Nobécourt, whose data are partly longitudinal, and Quaade provide controls from the records of children they have examined themselves.

The results of these studies are summarised in table 4, where it will be seen that in each of the controlled groups the obese boys show signs of puberty early, and that there is a higher incidence of pubertal changes among Bruch's boys aged 11⁻ and 12⁻ than in any of the control groups.[3] This general indication that early puberty may be associated with childhood obesity is supported by comparing the figures in table 4 with those reported by Tanner ('55) for 188 British military cadets whose mean endowment of endomorphy was as low as 3.09. He found that only 19.8% of them had pubic hair by the age of 12 years and 58.3% by the age of 13.

3. Growth Curves. Another approach to this problem is to compare the growth curves of the various groups of boys. Faster than average skeletal maturation is associated with an early pre-pubertal growth spurt. In boys the effect of this is to make the average stature of early maturers, aged about 8 to 11 years, greater than that of a group of slower maturers of the same age. Mean growth curves of the four groups of obese boys are compared with the controls chosen by the respective authors in figure 3. Nobécourt ('37) and Quaade ('55) again provided their own controls, and Bruch ('38) compared the stature of her boys with the tables of Burgess ('37). Wolff ('55) used two different sets of controls in his paper, one a group of American boys and the second the sons of well-to-do British parents studied by Widdowson ('47). Because they were racially more similar to Wolff's group, the latter were used for the present purpose. It should be borne in mind that these controls were economically more favored than Wolff's study group, and therefore any height advantage the latter might have over controls living in an identical environment would not necessarily be apparent. Nevertheless, it will be seen that, except for the Danish group, the obese boys age for age become progressively somewhat taller than the controls, the difference being maximal between the 9th and 11th years; then their lead falls off, until by the age of 13 years the controls have caught up and passed the obese groups. Stuart's ('55) case (not shown in figure 3) follows the same pattern.

In figure 4 mean stature for age for all the 229 boys is compared with that of the 22 most predominant ectomorphs and the 27 most predominant mesomorphs in our own study group. This also shows that obese boys apparently mature more rapidly and that they appear to become smaller adults. This is consistent with Sheldon's own data (Sheldon, Stevens and Tucker, '40), as is demonstrated in table 5.

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[3] The Copenhagen percentages are estimated from a regrouping of Quaades' ('55) data.

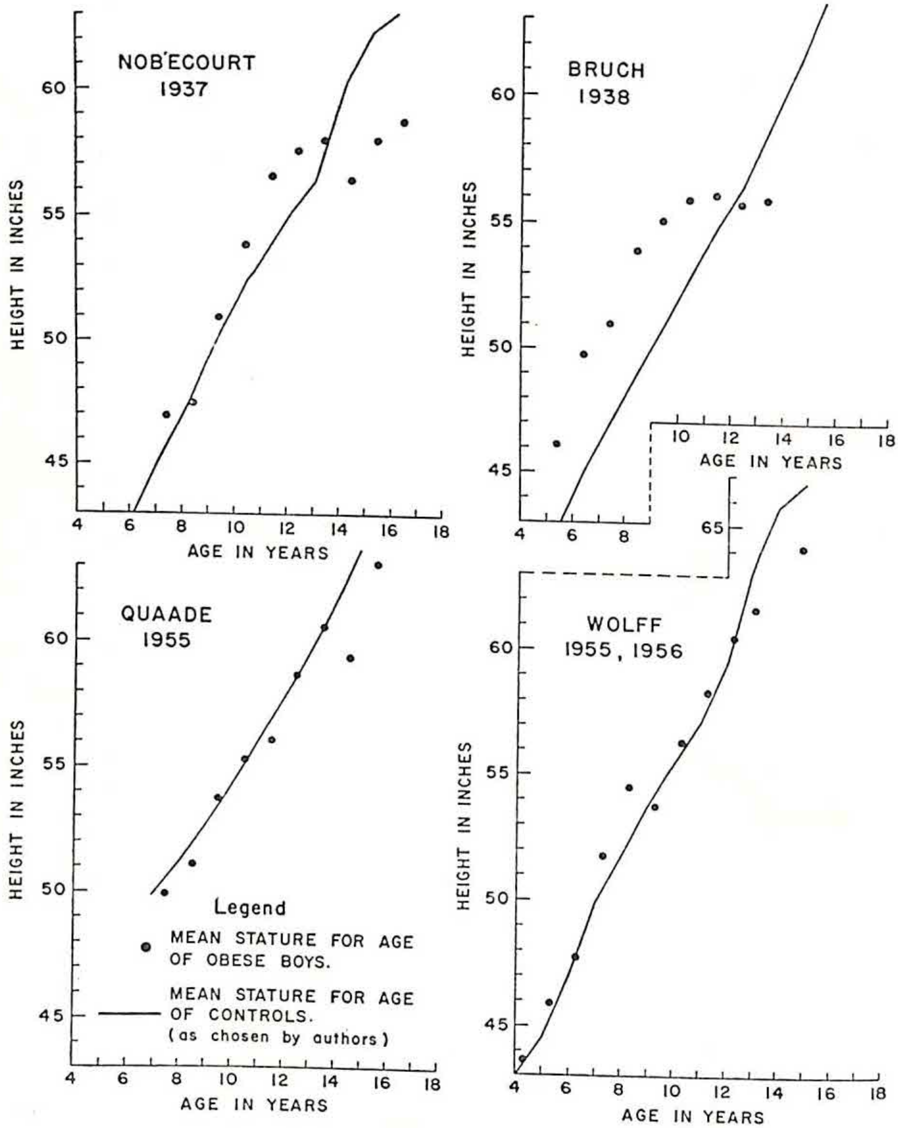

FIG. 3. THE MEAN STATURE OF FOUR GROUPS OF OBESE BOYS REPORTED IN THE LITERATURE, COMPARED WITH CONTROLS OF THE RESPECTIVE AUTHOR'S CHOOSING. NOBÉCOURT AND QUAADE PROVIDED THEIR OWN CONTROL DATA, BRUCH USED THOSE OF BURGESS ('37), AND WOLFF THOSE OF WIDDOWSON ('47).

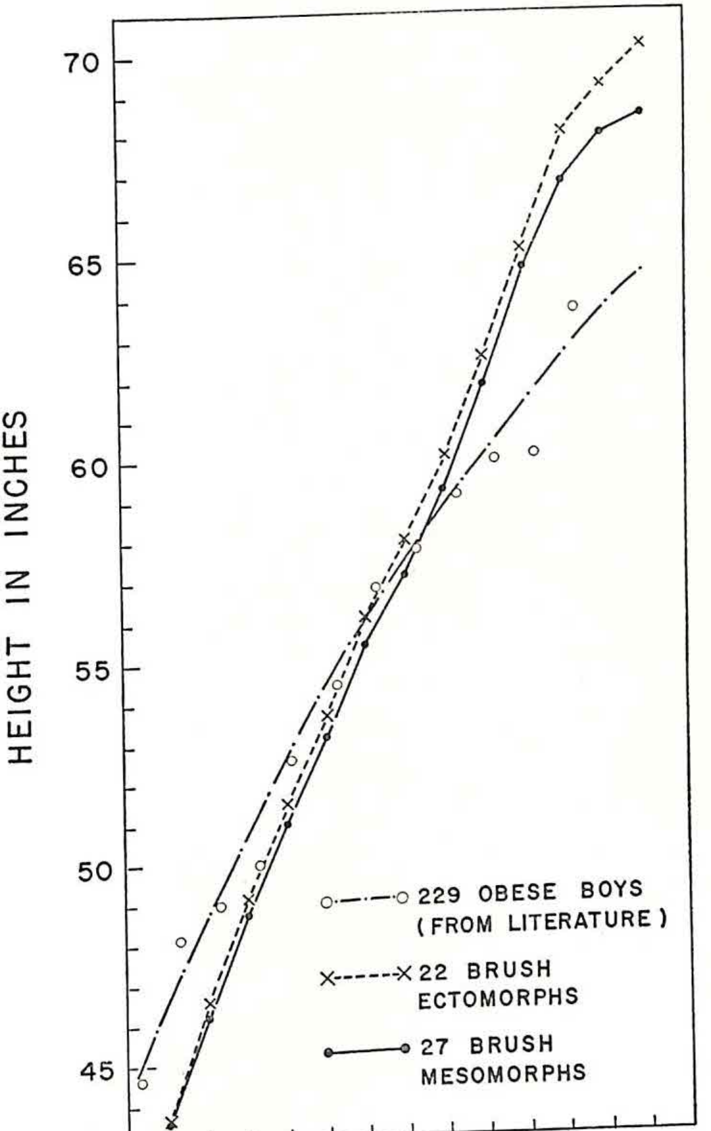

FIG. 4. MEAN STATURE OF ALL THE CASES SHOWN IN FIGURE 3 COMBINED, COMPARED WITH THE BRUSH ECTOMORPHS AND MESOMORPHS.

TABLE 5

The mean adult stature of groups of men showing a rating of over 5 in each of the somatotype components

(Computed from the data of Sheldon, Stevens, and Tucker ’40)

COMPONENT	NUMBER OF CASES	MEAN STATURE (IN INCHES)
I (Endomorphy)	516	67.94
II (Mesomorphy)	1,046	68.42
III (Ectomorphy)	862	70.46

With the possible exception of Bruch’s data, none of these studies taken by itself shows a relationship between endomorphy and rapid skeletal maturation which is statistically significant. Nevertheless, there is a consistent trend for the fastest maturers to be found among boys who are predominantly endomorphic.

DISCUSSION

Interpretation of Findings

The Brush Foundation data are probably the best suited of all the growth studies so far completed for an analysis of this type. It has been shown repeatedly that adverse enviroment can slow skeletal maturation (Stettner, ’20, ’21; Greulich, ’51; Beresowski and Lundie, ’52; De Wijn, ’53; Greulich, Crismon, and Turner, ’53). Adverse environment can also cause a dissociation of the relationship between skeletal maturation and growth, and therefore bring about stunting (Acheson and Hewitt, ’54). Since the Brush children were all from prosperous Cleveland homes, the economic environment was probably as constant as it is ever likely to be in any growth study. Nevertheless, different environmental effects almost certainly were experienced by the children. For instance, it was shown in the Oxford Study that the ordinary intercurrent illnesses of childhood could cause a dissociation of the relationship between skeletal maturation and growth, and this was similar to that caused by poor economic circumstances. Furthermore, there was no indication that a child so affected made any compensation for this stunting up until the age of 5 years (Hewitt, Westropp, and Acheson, ’55). Stuart (’56), in a longitudial study of a group of Boston children at the Harvard School of Public Health, has accumulated some evidence suggesting that emotional disturbances may be associated with or followed by delays in the progress of physical development. In one boy, a marked psychological reaction to his mother's death and to the resulting broken home was followed by profound retardation in his physical growth and adolescent development which extended over a number of years. The Brush children certainly suffered childhood diseases, and some of them were also subjected to emotional disturbances. Unforunately the records are not suitable for a detailed analysis of the influence of these factors, but we must assume that in many of the children interference with development did occur.

In this paper we have assembled evidence which suggests that there is a relationship between physique and rate of maturation. This relationship is presumably genetically determined, but even in such highly selected material it must have been progressively masked and distorted by the insults and stresses of the environment. All the evidence suggests that this distortion always takes the form of slowing down maturation and slowing down the growth rate even more—that is to say, reducing final adult height. Thus, upon the basic genetic tendency for slow maturation to be associated with great adult height is superimposed environmental tendency for slowed maturation to be associated with stunted adults (the word "stunted" being used in a comparative sense). Except in the case of children who show opaque lines at the metaphyses of their long bones on the radiograph (Harris's Lines), it is unfortunately impossible, at the moment, to distinguish between the naturally slow maturer and the slowed maturer. We have already shown that the naturally slow maturer is often predominantly ectomorphic. The position of any point in the scattergram in figure 1 could therefore depend on two factors. The first is the amount of ectomorphy in the individual's make-up; a considerable amount of this would tend to put him in the bottom right hand corner of the chart. The second is the effect the environment has had upon him (this in turn depends both upon the severity of his experience and his ability to withstand this experience); stresses of this type would tend to put him in the bottom left hand corner of the chart. Thus the mesomorph presumably appears in the top left hand corner of the chart, because he lacks the slowing effect which is associated with ectomorphy, and because he has not shown undue ill effects from his experience with his environment. Certainly, the mean value of 2.02 for ectomorphy in the mesomorphs of our group is very low. The computation of partial linear regressions in our material showed that a moderate endowment of endomorphy contributed little to the general rate of skeletal maturation as calculated in this study, so that Component I has evidently had little to do with the location of the points in figure 1. This is not, at first sight, consistent with our review of the literature, from which we concluded that the fastest maturers of all may be found among those with a high endowment of endomorphy.

This apparent inconsistency may be due to several things. To begin with, the regressions between rate of maturation and physique may not be linear, but may take a more complex form. Second, a true expression of the rate of maturation presents a difficult fundamental problem. The construction of the index we have used rested on the hypothesis, previously widely accepted, that the rate of maturation in the majority of individual children bears a constant relationship to the mean rate of maturation. It was realised from the outset that this hypothesis would be false in those children who suffered a setback in physical development through illness or some similar cause. Our finding that the rate of maturation in each indicator series may vary according to physique suggests that there may also be cases in which, because of physique, the index may not reflect the whole truth. Nevertheless, this fortifies our conclusions, for trends which have been detected with a clumsy instrument will often become obvious relationships when delicate techniques are evolved.

Application of Findings

One of the principal purposes of all growth studies has been to try to learn enough of the factors controlling physical development to enable the physician to evaluate the developmental status of an individual child. It has long been realized that height for age tables or weight for age tables are inadequate for this purpose. However, Wetzel ('41), by combining the three variables (height, weight, and age) produced a simple chart which was a definite step forward. If our present findings are valid, somatotype assessment and knowledge of skeletal maturity status of the child can also be powerful aids to the pediatrician in the diagnosis of minor deviations from the healthy patterns of physical development.

By expressing a child's height in terms of its skeletal maturity status at any age, a prediction of its adult height can be made. This procedure is the basis of the height prediction tables of Bayley and Pinneau ('52), and of Bayley's ('56) more recent growth curves. However, the present data suggest that we can go further than this. Supposing that endomorphy is associated with rapid maturation and rather short adult stature, we can then allow for this when we are trying to decide whether a fat boy is growing normally. It is interesting to note that when Bruch ('38) plotted "height age" against "skeletal age" for obese boys, she found it to be below average, although both stature and skeletal age when plotted against chronological age were above average for the same group of boys. In this way she showed that her study group were growing quickly and maturing quickly, but that they were going to be small adults.

Probably the best example of these principles would be the case of the delicately constructed, ectomorphic boy. Because he is highly endowed with the third somatotype component, there would be no need for concern if he were found to be maturing rather more slowly than average, nor would it necessarily be disturbing to find that his stature were rather less than that of children of the same age. However, if his stature was plotted against his skeletal maturity status and found to be less than average, this finding would strongly suggest faulty growth. Ectomorphy seems to be associated with greater than average adult stature, and therefore an ectomorphic boy should be taller than the average for his skeletal maturity status throughout the entire developmental period.

Ideally, it should be possible to draw up tables in which stature predictions can be made for all ages, allowing for all these variables. At the moment, however, there are far too many unknown factors for this project to be undertaken. Figure 1 shows that there is a wide variation among the ectomorphic and mesomorphic groups themselves. Part of this variation is certainly due to the environment, but there may be other factors as well. What is the effect of race? There is some evidence that the southern Italian woman matures more quickly than the Scandinavian woman, for instance. Is this simply because the former are usually highly endowed with endomorphy and the latter more ectomorphic in build, or does their ethnic pattern of itself contribute to the difference? Can climate have a direct effect on growth patterns? Again, it has been shown that adverse environment affects the development of the sexes differently, and that the temporary effect, at least, is more profound upon the boy than it is upon the girl (Greulich, '51; Greulich, Crismon, and Turner, '53; Acheson, Hewitt, Westropp, and Macintyre, '56). Does the resilience of any individual boy depend upon the amount of any single somatotype component, or even upon a reasonably equal distribution of all three components? Until these questions can be answered there seems to be little point in attempting to improve upon the standards of Wetzel ('41) or of Bayley ('56). Nevertheless, it may be helpful to bear in mind the possible effect of physique when making a clinical appraisal.

SUMMARY

One hundred and twenty-eight boys, originally followed in the Brush Foundation Growth Study, were again seen in 1951. Each had his height and weight recorded and was photographed for somatotyping. Their skeletal maturity, together with that of 97 other Brush boys, amounting to a total of 225 in all, was assessed, by the Oxford Method, from serial radiographs of hip and pelvis. When the boys who were somatotyped were divided into four groups according to rate of skeletal maturation during the growing period, it was found that the linear regression between Component III (ectomorphy) and rate of maturation differed significantly from zero, Component III being highest among the slow maturers. There was a tendency, which was not significant, for Component I (endomorphy) and Component II (mesomorphy) to be higher among the faster maturers.

When the 22 boys with over 5 in Component III were compared with the 25 boys with over 5 in Component II, it was found that the former were significantly taller and slower maturing than the latter. A detailed comparison was made between the maturational time-pattern in an articular epiphysis (head of femur), traction epiphysis (greater trochanter), and primary center (junction of pelvic and ischial rami) in the extreme ectomorphs and extreme mesomorphs. The numbers were too few at any age for statistical analysis, but it seemed that these time-patterns did vary with physique.

A critical analysis of the literature suggested that the fastest maturers may be found among those with a high endowment of Component I.

It is concluded that there is some basic relationship between physique and skeletal (or sexual) maturation, which is genetically controlled. However, it is emphasized that this relationship is masked and distorted by the effects of the environment. Finally, it is suggested that consideration of physical build may be of aid to the physician in his attempt to diagnose deviations from normal patterns of growth and skeletal maturation in children.

ACKNOWLEDGMENTS

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THE EFFECT OF SEX, BIRTH RANK AND BIRTH WEIGHT ON GROWTH IN THE FIRST YEAR OF LIFE[1]

BY EVA J. SALBER[2]

GROWTH in the first postnatal year, of babies of the four racial groups attending municipal child welfare clinics in Durban has been discussed previously (Salber, '57). This article analyses the effect of sex, birth rank and birth weight on that growth.

MATERIAL USED AND METHOD OF ANALYSIS

The same sample of babies is used here as was used in the previous paper, but the children are divided into Rank 1 (first-born) and Rank 2+ (later born), the numbers being:

EUROPEAN	RANK 1	RANK 2+	TOTAL
Male	458	658	1116
Female	417	563	980
Total	875	1221	2096
COLORED			
Male	79	205	284
Female	85	210	295
Total	164	415	579

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[1] This paper forms part of the material of an M. D. Thesis, University of Cape Town.

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BANTU	RANK 1	RANK 2+	TOTAL
Male	182	446	628
Female	150	525	675
Total	332	971	1303
INDIAN			
Male	80	179	259
Female	70	180	250
Total	150	359	509

The European babies are also divided into 5 different groups according to their weight at birth:

Up to 4 lbs 15 oz
5 lbs 0 oz to 5 lbs 15 oz
6 lbs 0 oz to 6 lbs 15 oz
7 lbs 0 oz to 7 lbs 15 oz
8 lbs and over.

Mean weights and standard deviation are worked out for each week of life from 2–52 weeks for boys and girls, Rank 1 and 2+ separtely in each birth weight group.

Since there are insufficient data on birth weights for the non-European groups and their numbers of first born babies attending clinic are also small, it is possible to analyse the effect of rank and birth weight in detail, and to graph the results only for the European group.

Rates of growth (increments) are also presented for boys and girls Rank 1 and Rank 2+ separately. These are shown at four-week intervals and are also expressed as number of ounces gained per week.

RESULTS

A. *Effect of Sex on Growth.*

1. *Mean Weights during the Year.*

Tables of mean weights at each week of life from 2–52 weeks for each of the racial groups. boys and girls separately, have been shown already (Salber, '57) and do not need to be repeated here. The boys' weight are higher than those of girls throughout the year but this is to be expected because boys weigh more than girls at birth. However, the difference between them is greater at the end of the year than at the beginning of the year (table 1).

TABLE 1

Weight differences between boys and girls of four racial groups at selected ages

BOYS–GIRLS	3 weeks (lbs)	13 weeks (3 mths) (lbs)	26 weeks (6 mths) (lbs)	39 weeks (9 mths) (lbs)	50 weeks (lbs)
European	0.39	0.66	1.03	1.06	1.34
Colored	0.40	0.91	1.24	1.34	1.21
Bantu	0.32	0.79	0.99	1.33	0.87
Indian	0.63	0.97	1.64	1.17	0.84

Examination of this table reveals that the difference in weight between boys and girls at three weeks is almost the same for European, Colored and Bantu, with Indians having the greatest difference. At 50 weeks difference is greatest for Europeans and least for Indians. European boys' weight rise steadily above those of girls throughout the year, Colored boys do the same until 39 weeks with a slight decline thereafter. The weight difference between Bantu girls and boys is less marked than for Colored until 39 weeks when it is the same, but after that the Bantu decline is steeper. Indians show the greatest weight disparity between boys and girls of all the racial groups up to 26 weeks, followed by an equally sharp drop thereafter so that at 50 weeks they have the least difference between boys and girls of all the groups.

2. *Shape of Growth Curves.*

The effect of sex on growth can be studied most simply by examination of the graphs of growth in the first year of life (Salber, '57) and by superimposing the graph for the girls on the graph for the boys in each race group. In general the shape of the growth curves in the first year of life is similar for boys and girls.

European. Growth curves of boys and girls run parallel to each other up to 10 weeks of age, after which there is a very gradual increase in the difference between them until the end of the year, with the boys consistently putting on slightly more weight.

Colored. Boys weights start rising faster than girls from two weeks of age, with a gradually increasing difference up to 33 weeks, after which the gap narrows very gradually but not sufficiently to enable the girls to catch up to the boys by the end of the year.

Bantu. Curves of growth of boys and girls are parallel up to 6 weeks, then the difference between boys and girls gradually increases up to about 6 months, weight of boys being greater than of girls. From 6 months till about 44 weeks there is no further increase in difference between the sexes, and after 44 weeks the gap narrows until at 49–50 weeks the difference in weights between boys and girls is virtually the same as at the beginning of the year.

Indian. Growth curves of Indian boys and girls are parallel to each other up to 7 weeks, from 7 to 32 weeks the difference narrows until by 51 weeks the difference is the same as at the beginning of the year.

In general it appears that non-European boys grow faster than girls during the first 6–8 months of life, and girls faster than boys during the rest of the year. European boys, however, consistently grow faster than girls throughout the year.

3. *Rate of Growth (increments).*

Tables showing rate of growth for boys and girls separately at four-week intervals were shown previously and commented on. (Salber, '57). The effect of sex per se on growth rate is now discussed.

European rate of growth is consistently higher for boys from 2–52 weeks, but the difference in growth rate is not as marked during the period 20–32 weeks as it is during the rest of the year. The total gain in weight for the sexes is as follows:

	BOYS	GIRLS
TOTAL GAIN 2–52 weeks	14.69 lbs	13.97 lbs

Colored rate of growth is higher for boys than girls for most of the year, but from 36 weeks, with slight irregularities, girls appear to grow faster than boys.

	BOYS	GIRLS
TOTAL GAIN 2–52 weeks	13.05 lbs	11.46 lbs

Bantu growth rate is higher for boys than girls with the exception of the period between 40–48 weeks when girls grow faster.

TOTAL GAIN	BOYS	GIRLS
2–52 weeks	14.30 lbs	12.64 lbs

Indian boys grow faster than girls from 2–32 weeks, but from 32 weeks onwards girls grow faster than boys.

TOTAL GAIN	BOYS	GIRLS
2–52 weeks	11.62 lbs	11.91 lbs

The same point emerges once again—the effect of sex on growth is not quite the same in the European and non-European races. In the non-European races there seems to be a period late in the second half of the first year during which the girls grow faster than the boys. Among Europeans this is not so, and boys grow consistently faster than girls.

B. *Effect of Birth Rank on Growth.*

Only in the European group are there sufficient data to analyse the effect of rank on growth fully, as the numbers of Rank 1 babies in the other groups are inadequate for analysis for half the year.

1. *Europeans.*

(a) Figures of mean weights from 2–52 weeks for ranks separately (Salber, '57) and chart 1 show that in European babies the rate of growth of Rank 1 (first born) babies, both boys and girls, is greater than that of Rank 2+ babies, since, although they start life with a lower birth weight (Salber and Bradshaw, '51), they end up heavier at the end of the year.

(b) At two weeks, Rank 1 girls weigh 0.49 lbs less than Rank 2+ girls, but they overtake Rank 2+ girls at 21 weeks and by 52 weeks are 0.38 lbs heavier. This means that from 2–52 weeks Rank 1 girls have actually gained 0.87 lbs more than Rank 2+ girls.

(c) At two weeks, Rank 1 boys weigh 0.21 lbs less than Rank 2+ boys, and do not overtake them until 42 weeks, but by 52 weeks they are 0.47 lbs heavier, thus gaining 0.68 lbs more during the year than Rank 2+ boys.

2. In the *Colored* group, information on Rank 1 babies is only available up to 27–28 weeks. By this time Rank 1 boys have not overtaken Rank 2+ boys. Rank 1 girls, however, overtake Rank 2+ girls at 17 weeks.

3. The *Bantu* group has information on Rank 1 babies up to 37–38 weeks. Rank 1 Bantu boys overtake Rank 2+ boys at 17 weeks, whereas Rank 1 girls overtake Rank 2+ girls at 29 weeks.

4. *Indian* group information on Rank 1 babies is complete up to 27 weeks. During this period the first born boys have not overtaken later born boys but the girls have done so at 24 weeks.

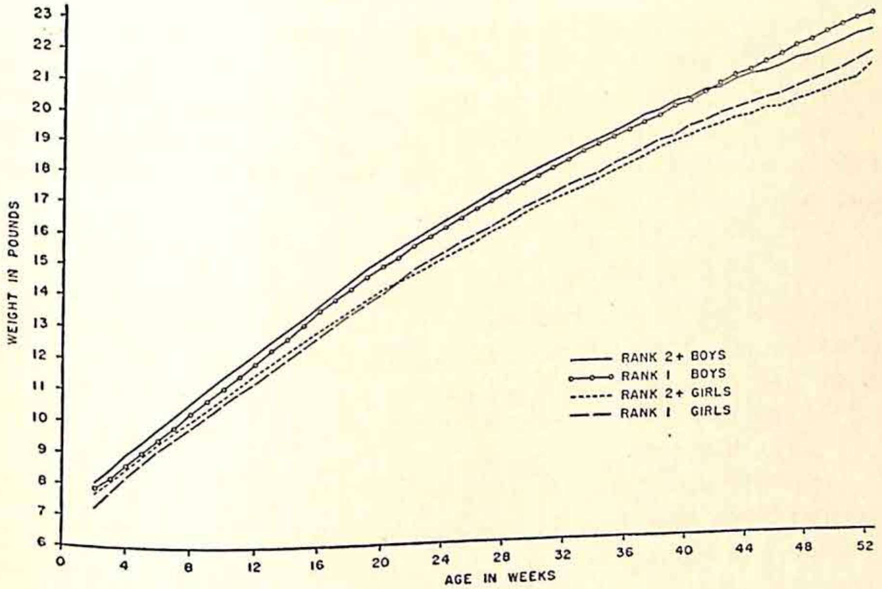

CHART 1.

GROWTH CURVES IN THE FIRST YEAR OF LIFE ACCORDING TO BIRTH RANK (EUROPEAN GIRLS AND BOYS SHOWING RANKS 1 AND 2 SEPARATELY).

5. In general, Rank 1 girls overtake Rank 2+ girls faster than Rank 1 boys overtake Rank 2+ boys. In the Bantu group, however, the position is reversed with Rank 1 boys overtaking Rank 2+ boys sooner than do the girls.

6. Examination of rates of growth (tables 2a and b) also show that in each racial group the gain per week is greater in Rank 1 than in Rank 2+ babies.

7. In European, Colored and Indian babies the difference in rate of growth between the ranks is greater for girls than for boys, but in the Bantu the difference appears to be greater in the boys.

TABLE 2a

Increments of Weight at 4 week intervals (Boys)

	RANK I								RANK 2+								ALL RANKS							
	EUROPEAN		COLORED		BANTU		INDIAN		EUROPEAN		COLORED		BANTU		INDIAN		EUROPEAN		COLORED		BANTU		INDIAN	
	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week
Birth Weight	7.35	—	—	—	—	—	—	—	7.63	—	—	—	—	—	—	—	7.48	—	—	—	—	—	—	—
0–2 Weeks	.59	–	—	—	—	—	—	—	.43	—	—	—	—	—	—	—	.50	—	—	—	—	—	—	—
2–4	.81	6.5	—	—	1.08	8.6	—	—	.90	7.2	1.11	8.9	1.26	10.1	—	—	.85	6.8	1.01	8.1	1.20	9.6	.85*	6.8
4–8	1.68	6.7	1.80	7.2	2.47	9.9	—	—	1.67	6.7	1.84	7.4	2.29	9.2	1.67	6.7	1.67	6.7	1.82	7.3	2.33	9.3	1.70	6.8
8–12	1.60	6.4	1.57	6.3	2.03	8.1	1.58	6.3	1.59	6.4	1.52	6.0	1.83	7.3	1.41	5.6	1.59	6.4	1.56	6.2	1.92	7.7	1.43	5.7
12–16	1.62	6.5	1.47	5.9	1.58	6.3	1.22	4.9	1.53	6.1	1.07	4.3	1.44	5.8	1.29	5.2	1.57	6.3	1.16	4.6	1.49	6.0	1.28	5.1
16–20	1.41	5.6	1.44	5.8	1.54	6.2	1.37	5.5	1.43	5.7	1.29	5.2	1.15	4.6	1.01	4.0	1.42	5.7	1.34	5.4	1.23	4.9	1.10	4.4
20–24	1.25	5.0	0.84	3.4	0.85	3.4	0.58	2.3	1.22	4.9	1.07	4.3	0.98	3.9	0.98	3.9	1.23	4.9	0.99	4.0	0.94	3.8	0.87	3.5
24–28	1.11	4.4	—	—	0.87	3.5	1.04	4.2	1.15	4.6	1.00	4.0	0.92	3.7	0.89	3.6	1.14	4.6	0.96	3.8	0.93	3.7	0.93	3.7
28–32	1.10	4.4	—	—	0.82	3.3	0.90	3.6	0.97	3.9	0.97	3.9	0.62	2.5	0.72	2.9	1.03	4.1	0.94	3.8	0.66	2.6	0.74	3.0
32–36	0.89	3.6	—	—	0.62	2.5	—	—	0.96	3.8	0.44	1.8	0.66	2.6	0.12	0.5	0.92	3.7	0.67	2.7	0.63	2.5	0.36	1.4
36–40	0.95	3.8	—	—	—	—	—	—	0.89	3.6	0.58	2.3	0.81	3.2	0.42	1.7	0.92	3.7	0.52	2.1	0.74	3.0	0.41	1.6
40–44	0.92	3.7	—	—	—	—	—	—	0.68	2.7	0.39	1.6	0.01	0	0.61	2.4	0.80	3.2	0.38	1.5	0.04	0.2	0.47	1.9
44–48	0.93	3.7	—	—	—	—	—	—	0.60	2.4	0.28	1.1	0.56	2.2	0.35	1.4	0.74	3.0	0.50	2.0	0.54	2.2	0.45	1.8
48–52	0.82	3.3	—	—	—	—	—	—	0.82	3.3	1.50	6.0	1.36	5.4	—	—	0.81	3.2	1.20	4.8	1.65	6.6	1.03	4.1
48–50	0.44	3.5	—	—	—	—	—	—	0.44	3.5	0.62	5.0	0.41	3.3	—	—	0.44	3.5	0.49	3.9	0.45	3.6	0.22	1.7
TOTAL 2–52	15.09	—	—	—	—	—	—	—	14.41	—	13.06	—	13.89	—	—	—	14.69	—	13.05	—	14.30	—	11.62	—
2–50 Weeks	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.32	—	12.35	—	13.10	—	10.81	—

* Assuming the gain per week for 2–4 weeks to be at least as great as that for 4–8 weeks.

TABLE 2b

Increments of weight at 4 week intervals (Girls)

	RANK I								RANK 2+								ALL RANKS							
	EUROPEAN		COLORED		BANTU		INDIAN		EUROPEAN		COLORED		BANTU		INDIAN		EUROPEAN		COLORED		BANTU		INDIAN	
	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week	Incr. (lb)	oz per week
Birth Weight	7.01	—	—	—	—	—	—	—	7.37	—	—	—	—	—	—	—	7.20	—	—	—	—	—	—	—
0–2 Weeks	0.24	1.9	—	—	—	—	—	—	0.37	3.0	—	—	—	—	—	—	0.35	2.6	—	—	—	—	—	—
2–4	0.97	7.8	—	—	1.27	10.2	—	—	0.84	6.7	0.61	4.9	1.16	9.3	—	—	0.88	7.0	0.67	5.4	1.17	9.4	0.72*	5.7
4–8	1.66	6.6	1.68	6.7	2.19	8.8	—	—	1.53	6.1	1.58	6.3	1.98	7.9	1.54	6.2	1.58	6.3	1.60	6.4	2.05	8.2	1.43	5.7
8–12	1.48	5.9	1.51	6.0	1.84	7.4	1.60	6.4	1.44	5.8	1.36	5.4	1.72	6.9	1.22	4.9	1.45	5.8	1.41	5.6	1.73	6.9	1.26	5.0
12–16	1.41	5.6	1.22	4.9	1.44	5.8	1.16	4.6	1.39	5.6	1.11	4.4	1.45	5.8	1.06	4.2	1.40	5.6	1.14	4.6	1.45	5.8	1.08	4.3
16–20	1.36	5.4	1.38	5.5	1.08	4.3	0.79	3.2	1.21	4.8	1.14	4.6	1.04	4.2	0.66	2.6	1.28	5.1	1.22	4.9	1.05	4.2	0.70	2.8
20–24	1.25	5.0	1.00	4.0	1.11	4.4	1.04	4.2	1.11	4.4	0.93	3.7	1.06	4.2	0.92	3.7	1.18	4.7	0.90	3.6	1.07	4.3	0.97	3.9
24–28	1.09	4.4	—	—	0.77	3.1	—	—	1.09	4.4	0.97	3.9	0.69	2.8	0.69	2.8	1.09	4.4	1.03	4.1	0.71	2.8	0.76	3.0
28–32	1.04	4.2	—	—	1.05	4.2	—	—	0.90	3.6	0.50	2.0	0.77	3.1	0.73	2.9	0.97	3.9	0.62	2.5	0.83	3.3	0.74	3.0
32–36	0.95	3.8	—	—	0.32	1.3	—	—	0.96	3.8	0.66	2.6	0.55	2.2	0.51	2.0	0.95	3.8	0.63	2.5	0.50	2.0	0.55	2.2
36–40	0.94	3.8	—	—	—	—	—	—	0.86	3.4	0.46	1.8	0.70	2.8	0.70	2.8	0.91	3.6	0.82	3.3	0.60	2.4	0.75	3.0
40–44	0.74	3.0	—	—	—	—	—	—	0.59	2.4	0.82	3.3	—.05	—.2	0.24	1.0	0.66	2.6	0.63	2.5	0.20	0.8	0.39	1.6
44–48	0.68	2.7	—	—	—	—	—	—	0.64	2.6	0.01	0	0.92	3.7	0.50	2.0	0.65	2.6	0.07	0.3	0.84	3.4	0.62	2.5
48–52	0.90	3.6	—	—	—	—	—	—	1.04	4.2	0.70	2.8	0.20	0.8	1.44	5.8	0.97	3.9	0.72	2.9	0.44	1.8	1.94	7.8
48–50	0.40	3.2	—	—	—	—	—	—	0.41	3.3	0.52	4.2	0.29	2.3	0.40	3.2	0.41	3.3	0.49	3.9	0.34	2.7	0.46	3.7
TOTAL 2–52	14.47	—	—	—	—	—	—	—	13.60	—	10.85	—	12.19	—	—	—	13.97	—	11.46	—	12.64	—	11.91	—
2–50 Weeks	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.41	—	11.23	—	12.54	—	10.43	—

* Assuming the gain per week for 2–4 weeks to be at least as great as that for 4–8 weeks.

C. *Effect of Birth Weight on Growth.*

Sufficient information on birth weight is available in the European group only (in the other groups birth weight is unknown for $\frac{1}{2}$-$\frac{3}{4}$ of each group). The European group is divided into 5 birth weight groups as mentioned earlier, but since the numbers of cases up to 4 lbs 15 oz in weight and 5 lbs 0 oz to 5 lbs 15 oz are too small for separate analysis, these two groups are combined. Table 3 shows the mean weights, boys and girls separately, for the different birth weight groups, all ranks combined.

From charts 2 and 3, which are the pictorial representation of table 3, it can be seen that:

1. Because of their superior birth weight, heavy babies at birth are heavier at the end of the year than babies who are light at birth. This is seen in each successive birth weight group.

2. Birth weight appears to have no effect on the gain in weight during the first year.

3. This means that the rate of growth is relatively greater for lighter babies.

4. These remarks apply equally well to both boys and girls.

DISCUSSION

Effect of Sex on Growth in First Postnatal Year.

Almost all investigators of postnatal growth give separate figures for boys and girls and invariably the boys' weight are greater than those of the girls. This may be because boys weigh more than girls at birth, or because they actually grow faster. In fact, both factors appear to play a part.

Simpson ('52) and Hammond ('52) both found that boys gained on average 1 lb more than girls during the year.

Thomson ('54) shows that in addition to gaining weight more rapidly over the year, the pattern of weight gain in boys is different. They appear to forge ahead more rapidly in the first 12 weeks than subsequently. Thompson ('54) points out that although male infants are larger than female infants of the same age and although their growth increments tend to be larger, the percentage rate of growth does not in general differ significantly in the two sexes. Hill and Magee ('38) also found that though the weight increment of boys

TABLE 3

Mean weights (in pounds) of European infants from 2–52 weeks
All ranks according to birth weight

WEEK	4 and 5		6		7		8	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
2			7.05	7.01	7.79	7.62	8.93	8.73
3	6.30	6.35	7.49	7.41	8.26	8.06	9.34	9.11
4	6.83	6.85	7.96	7.81	8.71	8.50	9.79	9.52
5	7.25	7.22	8.42	8.21	9.18	8.92	10.21	9.92
6	7.68	7.62	8.88	8.64	9.62	9.34	10.63	10.32
7	8.10	8.00	9.33	9.04	10.05	9.73	11.06	10.71
8	8.47	8.34	9.74	9.45	10.50	10.12	11.46	11.06
9	8.89	8.77	10.14	9.83	10.91	10.50	11.87	11.43
10	9.25	9.11	10.55	10.23	11.31	10.87	12.27	11.78
11	9.69	9.47	10.93	10.56	11.71	11.24	12.67	12.10
12	10.09	9.82	11.33	10.93	12.12	11.61	13.07	12.47
13	10.53	10.20	11.75	11.23	12.51	11.97	13.43	12.84
14	10.92	10.53	12.18	11.58	12.89	12.33	13.81	13.18
15	11.33	10.90	12.55	11.88	13.30	12.69	14.18	13.53
16	11.67	11.25	12.95	12.22	13.69	13.02	14.56	13.88
17	11.99	11.60	13.31	12.55	14.07	13.37	14.92	14.20
18	12.40	11.90	13.64	12.92	14.41	13.69	15.29	14.52
19	12.78	12.17	13.93	13.21	14.78	14.02	15.63	14.87
20	13.17	12.44	14.30	13.53	15.12	14.36	15.99	15.18
21	13.48	12.72	14.58	13.85	15.45	14.65	16.32	15.50
22	13.85	12.99	14.83	14.12	15.76	14.96	16.64	15.78
23	14.14	13.21	15.10	14.41	16.07	15.30	16.97	16.04
24	14.46	13.60	15.39	14.72	16.36	15.61	17.32	16.26
25	14.73	13.83	15.70	15.00	16.64	15.85	17.59	16.53
26	15.00	14.10	15.99	15.27	16.93	16.17	17.90	16.79
27	15.31	14.42	16.28	15.55	17.22	16.44	18.17	17.07
28	15.51	14.82	16.60	15.79	17.51	16.69	18.45	17.35
29	15.79	15.00	16.85	16.01	17.80	16.94	18.70	17.61
30	16.01	15.29	17.05	16.26	18.10	17.22	18.99	17.86
31	16.31	15.52	17.30	16.50	18.36	17.48	19.22	18.12
32	16.53	15.67	17.67	16.72	18.54	17.73	19.47	18.30
33	16.78	15.92	17.86	16.94	18.80	17.93	19.76	18.49
34	16.96	16.19	18.12	17.20	19.00	18.15	19.94	18.75
35	17.31	16.44	18.38	17.44	19.20	18.42	20.16	19.00
36	17.54	16.73	18.61	17.68	19.41	18.66	20.38	19.19
37	17.75	17.02	18.76	17.95	19.73	18.84	20.62	19.42
38	18.05	17.14	19.02	18.19	19.95	19.12	20.73	19.73
39	18.25	17.47	19.21	18.44	20.22	19.33	21.07	19.94
40	18.43	17.50	19.46	18.63	20.45	19.51	21.23	20.16
41	18.59	17.79	19.73	18.80	20.68	19.72	21.43	20.36
42	18.68	17.87	19.95	18.97	20.86	19.88	21.61	20.54
43	18.85	18.12	20.10	19.17	21.14	20.05	21.87	20.72
44	19.11	18.11	20.26	19.33	21.28	20.24	22.03	20.80
45	19.16	18.29	20.42	19.55	21.51	20.43	22.20	20.91
46	19.34	18.33	20.53	19.75	21.66	20.52	22.50	21.04
47	19.73	18.60	20.77	19.94	21.86	20.75	22.64	21.23
48	19.88	18.68	21.09	20.09	21.93	20.91	22.85	21.36
49	20.01	19.01	21.39	20.18	22.22	21.13	23.03	21.60
50	20.32	18.94	21.54	20.34	22.31	21.31	23.36	21.88
51	20.46		21.73	20.43	22.51	21.59	23.63	22.14
52	20.86		21.62	20.71	22.50	21.86	24.01	22.60

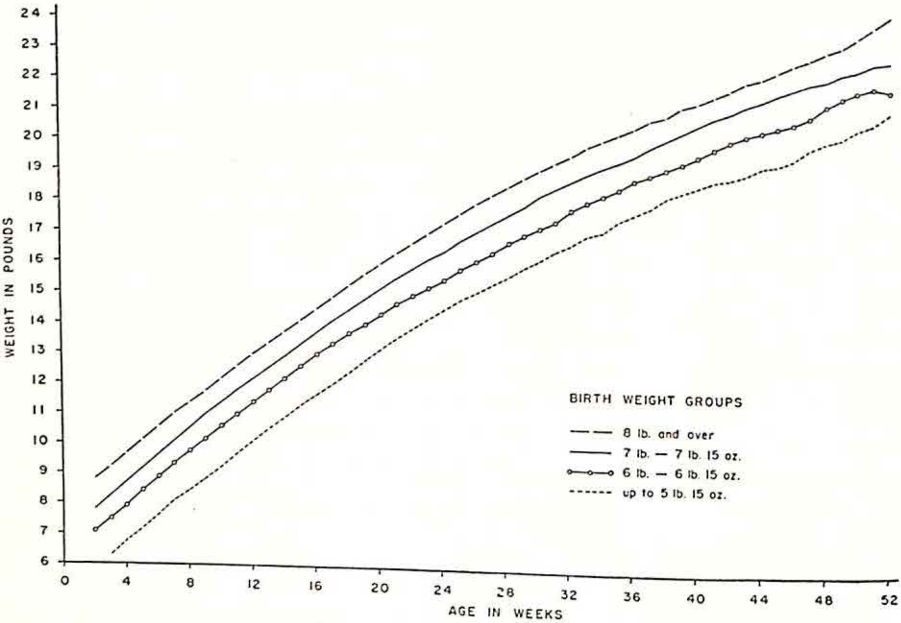

CHART 2.

GROWTH CURVES IN FIRST YEAR OF LIFE ACCORDING TO BIRTH WEIGHT (EUROPEAN BOYS SHOWING BIRTH WEIGHT GROUPS SEPARATELY).

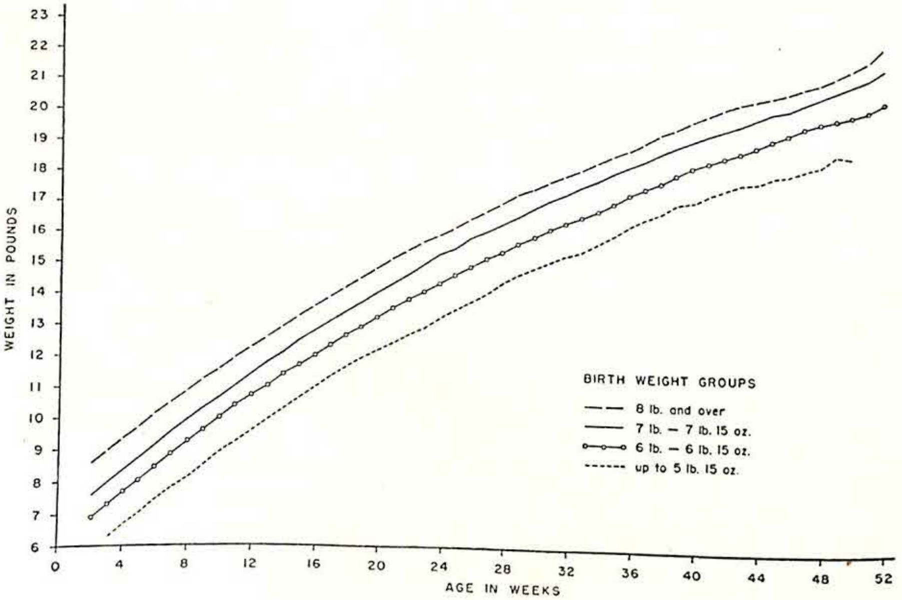

CHART 3.

GROWTH CURVES IN FIRST YEAR OF LIFE ACCORDING TO BIRTH WEIGHT (EUROPEAN GIRLS SHOWING BIRTH WEIGHT GROUPS SEPARATELY).

slightly exceeds that of girls at each age; relatively there is little difference between them (*i.e.*, in increases as a percentage of weight at the end of the preceding period).

Norval *et al.* ('51) state that boys are longer and heavier than girls of the same age, and boys are also heavier than girls of the same length. The growth rates of length and weight are somewhat larger for boys than girls at the beginning of the year, but approach equality by the end of the year.

Parfit ('51) compared average weights at successive age periods in the first year, and found a significant difference between the boys and girls, which progressed with age. At birth her boys were 4 oz heavier than girls, at 6 months 20 oz, and at the end of the year 26 oz. This showed that the difference in rate of gain which had started prenatally continued for at least 12 months. However, examination of her figures shows that in the early period the boys have grown much faster than later in the year.

On the whole certain facts can be deduced from the foregoing:

1. Mean weight of boys are greater than those of girls throughout the first year of life.

2. Rate of growth of boys is faster than that of girls throughout this period, but the difference in rate of growth is greater in the first 6 months of life than in the second 6 months.

The present investigation confirms these findings for European babies. European boys are about a pound heavier at the end of the year than European girls. They grow faster than the girls throughout the year, but the difference in their growth is greater in the first than the second 6 months of life.

The non-European pattern is rather different. Mean weights for boys are still greater than those for girls, Colored difference being slightly less than European, and Bantu and Indian less than Colored. Deviation from the usual pattern appears in the rate of growth.

If we express table 1 somewhat differently and compare the differences in weight of boys and girls at successive periods we see this quite clearly.

In Europeans boys always maintain a faster rate of growth than girls. In the other three groups in Colored and Bantu from 39–50 weeks and in Indians as early as 26–39 weeks this trend becomes reversed. In other words, in those periods girls are actually growing faster than boys. They do not catch up with the boys by 50 weeks, partly because of the superior birth weight of the boys but the total gain of weight of Indian boys and girls is almost the same from 2–50 weeks and, if one can accept the 52 weeks figure, is actually greater than that of the boys from 2–52 weeks. Bantu still show a difference in favor of boys in total gain from 2–50 weeks of about ½ lb and Colored about 1 lb but there is no question of the direction of the growth and it would seem that if one could follow these children into the second year of life one might find the girls to be actually heavier than the boys.

TABLE 4

Comparison of weight differences of boys and girls at successive periods

	3–13 weeks (lb)	13–26 weeks (lb)	26–39 weeks (lb)	39–50 weeks (lb)
European	+.27	+.37	+.03	+.28
Colored	+.51	+.33	+.10	—.13
Bantu	+.47	+.20	+.34	—.46
Indian	+.34	+.67	—.47	—.33

+ Boys grow more rapidly than girls.
— Boys grow less rapidly than girls.

Phillips ('53) in a study of South African nursery school children (European and Bantu) found that unlike the European, Bantu girls were superior in weight though not in height, to Bantu boys. He also quotes a study by Robertson ('52) where Bantu pre-school girls were heavier and taller than boys. Kark ('52) discussing Bantu school children in Pholela also found when he compared them with European, American, and White South African figures, that the Pholela boys were somewhat more retarded in stature and weight than the Pholela girls and had a higher incidence of clinical signs of malnutrition.

It would be most interesting to see whether the same remarks apply to Colored and Indian pre-school and school children, if the information were available, but even on Bantu data only, it is possible that girls start growing faster than boys from some point in the first year of life, and it is possible that the differences in rate of growth of Indian boys and girls would be found to be even greater if follow-up studies could be done.

The reason for this difference in growth rate in non-Europeans can only be speculative at this stage. We know that boys are biologically inferior to girls at least as far as mortality rates are concerned. It is quite possible that in adverse conditions, girls do better than boys as far as growth is concerned. In this connection it is most interesting to see that the Indian infants whose diets and general rate of growth in the first year of life are the poorest of the four races, show the increased rate of growth of girls at an earlier age than that shown by the Bantu and the Colored.

Effect of Birth Rank on Growth.

Wardlaw and Dart ('32) remark on the unique position which the first born male of a family occupies in the social organization of many peoples, and are surprised that differences between first and later children are so infrequent in literature dealing with growth of children. "In the biblical writings there are, indeed, many instances in which the expression 'first born' is used to connote the possession of superior or outstanding qualities of some kind. But no clue is given to the nature of the qualities which the first born, in the literal sense, might be supposed to show. Any distinguishing qualities of the first born male which may exist have been obscured by the fact that only approximately half the total number of first born males are first children. The occurrence of first born female children is usually not taken into account."

A summary of their findings on the relationship between the weight of breast fed babies and their order of birth is as follows:

"The earlier infants of a moderate sized family tend to be lighter than those born later.

"For breast fed infants a similar relation between weight and order of birth holds up to an age of about six months.

"The growth of the infants of primiparae tends to be retarded more during the first four weeks of life than the growth of later children.

"The relatively heavier, later children of a family have available a more plentiful supply of breast milk than the earlier, lighter children."

Pearson ('14) states that "the growth of the first child is hampered by conditions which exist to a far less extent for the following births."

However, desipte this handicapping, there is evidence to suggest that first children grow better than later born children, at least in the first year of life.

Meredith ('50) reviewed the literature on birth order and body size.

He quoted Schmid-Monnard ('92) who found that the relationship between birth order and body weight became reversed during the first postnatal year. Children of "old pluriparae" were heavier in early infancy than those of "young primiparae" but the latter were heavier in the second half of the first year. Meredith concludes that the available evidence in late infancy and childhood shows that body weight is inversely related to birth order.

Hewitt and Stewart ('52) found that parity was an important source of variation in birth weight and subsequent weight gain. The birth weight of first born babies was distinctly below average, but by the end of the year these babies were slightly heavier than subsequent babies.

MacKinlay ('26) investigated working class families in slum areas of Glasgow. With regard to position of a child in the family and its weight and height, his findings were that infants of the first and those over the eighth pregnancy, were lighter and shorter than those of the in-between pregnancies. "The inferiority of the first born, however, is replaced at the end of the year by a definite superiority both in height and weight, while that manifested in the early months by the last born of families over eight is still apparent at the end of the year."

MacKinlay says that maternal morbidity is most frequent in first pregnancies and the high incidence of deformed pelves in a slum community magnifies the dangers of parturition. The difficulty and length of a first labor is associated with greater shock to first infants. But, as the age of the mother increases, and with it, the number of pregnancies, the environmental conditions change, and infants of later pregnanices may be born in over-crowded houses, in conditions of poverty and with exposure to infectious diseases more likely. First children, despite their low initial birth weight, may be expected to overcome their deficiencies if they receive good care, whereas later born childern, particularly in big families of low income, would of necessity get less care, and MacKinlay considers that the relationship of weight in infancy to the position of a child in the family is a secondary result of the efficiency with which the mother supervises her infant.

Hammond ('52) showed that later born children, especially girls, had a lower increase in weight in the first year. First born babies of both sexes gained more weight in the first year than the second, third and fourth born.

Cawley *et al.* ('54) also found positive correlations at birth between weight and birth rank (and between length and birth rank)—these correlations were rapidly eliminated after birth and at two years had become negative. These authors agree with MacKinlay in attributing the reason for this negative correlation to be the association between place in family and socio-economic circumstances. First born children are more favorably placed than later born because well-off parents have small families and because poor parents are better off at the birth of their first children.

The present findings confirm the evidence that first born babies, although they start life with a lower birth weight, overtake later born babies and end up heavier at the end of the year. This result is found in both boys and girls.

Although data for non-European groups are insufficient for full analysis, the same results apply. In European, Colored and Indian babies, first born girls overtake later born earlier than first born boys overtake later born boys. In the Bantu the position is reversed for boys and girls. I can find no explanation for the difference in this respect.

Effect of Birth Weight on Growth.

Illingworth *et al.* ('49) demonstrated that birth weight had a constant and very important relationship to subsequent weight at all ages studied from 4–13 years. Throughout childhood the child who was small at birth weighed less than the child who was big at birth. Illingworth ('50) in another study of children up to three years of age, found that the same rule held. For example, his average male child who at birth weighed 9½ lbs or more, weighed more at one year than the child whose birth weight was 5½ lbs or less, weighed at two years.

Lowe and Gibson ('53) found the mean weight at the third birthday to be closely related to birth weight; the correlation between them (with birth order and duration of gestation held constant) being +0.49 for males and +.50 for females.

Drillien ('48) also found that at any given age (up to four years) average weight rose steadily with increasing birth weight.

Cullumbine ('53) investigating the health of a tropical people obtained the same results for the children of Ceylon. In one group of 327 children the weight at birth was positively correlated with the weight at 15 months $r = +0.468$, at three years $r = +0.496$ and at 6 years $r = +0.423$

Parfit ('51) f[illegible]ilar results in the first year of life—namely, that children mantained their relative weight position at the end of the year according to their weight at birth. She makes the point, however, that the weight actually gained from birth was the same for babies of all birth weights. The rate of growth was greater for small babies than for large.

Similar conclusions on the lack of association between gain in weight and birth weight were reached by the Divisional Medical Officer, Lancashire County Council ('50), by Simpson ('52) and by Hammond ('52).

Norval *et al.* ('51) state that the observation of the weight at the end of the year being dependent on the weight at birth is a very old one, and quote Camerer who showed this as early as 1893. They make the point, however, that with the same amount of weight gain in two children, the smaller child will have a larger percentage increase in weight. They found additional evidence by correlating birth weight with absolute gain of weight during the year. In both boys and girls the regression was negative; that is, the amount of growth is larger for smaller children than for larger children.

Hill and Magee ('38) also agree that lighter babies have a relatively greater increase in weight gain than heavier babies. For instance, between the 4th and 28th week the lighter babies (male and female) rather more than doubled their birth weight, whereas the heavier group increased by 86%. Between the 28th and 52nd week the lighter group increased by 36% for males, 33% for females, and the heavier group by 27% and 31%, respectively.

Herdan ('54) says that the relationship between birth weight and subsequent weight is not constant but decreases with increasing age, which is to be expected since in the early stages of life body weight exceeds birth weight by only a small amount, but as weight increases with age, birth weight becomes relatively smaller and less important compared with additional weight after birth. At three years of age he assesses the effect of birth weight as accounting for not more than 25% of the variation in subsequent weight.

Thomson ('54) states that "it is wrong to say, and still worse to teach, that infants double and treble their birth weight at a fixed age." Thus he agrees with Parfit who made the same point in her investigation. The Divisional Medical Officer's Report referred to previously gives a table of expected weights at one year, which certainly shows this rule to be inaccurate.

Hahn ('55) found that two-thirds of the infants he surveyed completed the doubling time between 14 and 22 weeks (*i.e.*, 3–5 months). The figures in this study also suggest that babies, particularly those lighter at birth, double their birth weight before 6 months. Taking all ranks together, boys and girls separately, European boys double their birth weight by 20 weeks (girls 21 weeks) and treble their weights by the end of the year. Using birth weights for non-Europeans given by Salber and Bradshaw ('51) it can be seen that Colored boys double their birth weight by 18 weeks (girls 20 week), Bantu boys by 14 weeks (girls 15 weeks) and Indian boys by 15 weeks (girls 14 weeks). Only Bantu males and females, and Colored males, however, have succceeded in trebling their birth weight by one year.

SUMMARY

1. Boys' weights are higher than those of girls throughout the first year of life.
2. European boys grow consistently faster than girls in the first year.
3. Non-European boys grow faster than girls in the first 6–8 months of life, but the girls grow faster than the boys thereafter.
4. It is suggested that in adverse environmental conditions, girls grow better than boys.
5. First born babies of both sexes start off lighter than later born babies at birth, but overtake them during the first year.
6. In Europeans, Colored and Indians the difference in rate of growth between the ranks is greater for girls than for boys, but in the Bantu it is greater for boys.
7. Because of their superior birth weight heavy babies at birth remain heavier throughout the year than babies who are lighter at birth.
8. Birth weight has no effect on gain in weight during the year.
9. This means that rate of growth is relatively greater for babies who are lighter at birth.
10. Babies double their birth weight before 6 months of age. This applies particularly to lighter babies and to non-European babies.

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BOOK REVIEWS

The Longitudinal Study of Individual Development. By LELAND H. STOTT. 115 pp. The Merrill-Palmer School, Detroit, 1955. $2.75.

There are two basic approaches in studying growth and development: One is cross-sectional where large numbers of individuals are measured for some factor at a particular age; data so obtained provide information, usually in the form of 'norms,' on the status of this factor at certain fixed ages. The other is the longitudinal approach where the *same* individuals are measured and followed over a number of years. This approach to the study of growth is more satisfactory for it gives valuable information about individual variations in the growth patterns of children and, most of all, provides data on the velocity of development. Not everyone is convinced of the efficacy of the longitudinal approach, for such studies are expensive to run, large quantities of data are collected, some considerable time is often needed to await results, and it is not always easy to keep in contact with the same children. The fact remains that there are many problems which can only be studied longitudinally and it is necessary to fight for its use. In making a case for the advantages of the longitudinal study, one important aspect is often forgotten: this is its teaching value.

In writing this book, Dr. Stott clearly had this in mind. Training in Child Development offered at the Merrill-Palmer School requires the student to follow a particular child over a number of years. Emphasis is placed on the "whole child" and an attempt is made to study all general factors concerned in his development. Dr. Stott presents to the student various methods and techniques useful in evaluating this highly complex process. The most valuable feature of the book is that, in discussing the methodology in general, he emphasizes the necessity for critically evaluating the various techniques. The actual presentation of the techniques for appraising developmental status and progress is fair, clear, and concise.

At the outset Dr. Stott discusses the general considerations necessary in studying the child longitudinally and this includes an excellent, simply presented section on basic statistical concepts. Appraising developmental status is discussed and it is divided into physical, behavioral, social, emotional and mental developments, and the evaluation of personality. A part of the book is given over to a description of the methods for tracing developmental progress and there is a clear general discussion on growth curves, both physical and mental.

Finally the author describes the factors that condition individual development, emphasizing the importance of the home and family environment and the necessity for its evaluation. There are 36 figures at the end of the book illustrating techniques; the references are adequate. The book is of a loose leaf type and is paper backed. The material is well presented and the printing clear.

Dr. Stott would be happy if his book stimulates even if we may criticize some of the tests and techniques. It certainly stimulated the reviewer and it can be strongly recommended to all students interested in the longitudinal approach in human biology.

Frank Falkner

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Louisville, Kentucky

Biochemical Individuality: The basis for the genetotrophic concept. By Roger J. Williams. xi + 214 pp. John Wiley, New York, 1956. $5.75.

This book is devoted to the discussion of the variability and individuality at the physiological and biochemical levels, with emphasis on what the author calls "genetotrophic" concept and its implications for the broad field of human biology. Some aspects have been discussed previously by the author in *The Human Frontier* (1946) and *Free and Unequal* (1953). The present volume is devoted in a more specific way to the implications of the concept for biology and medicine.

The idea of human variability has been present in the mind of physicians since Hippocrates, and the growth of medical knowledge has been continuously showing the importance of individaul characteristics in the genesis and course of disease in man. The development of "constitutional pathology" represents an attempt to establish the significance of such differences (cf. G. Draper, *Human Constitution in Clinical Medicine*, 1944).

The genetotrophic principle as conceived by the author postulates that every organism, with its distinctive genetic background, has also distinctive nutritional needs that must be met for optimal well-being.

The concept gives scientific support, based on the present biochemical knowledge, to some old observations. The popular dictum "One man's food is another man's poison" is a good expression of this idea. Much the same thought has been expressed by no lesser food expert than Brillat-Savarin, who said: "Tell me what you eat, and I'll tell you what you are."

The genetotrophic concept affects human biology in two main ways: (1) It calls attention to the significance of biochemical differences between "normal" individuals, and to their genetic basis; (2) it makes possible the correction of these differences by adequate food supply, should they be of consequence in the development of pathological conditions. In this last aspect the concept has obvious importance both for clinical and preventive medicine. The author considered the implications for the biological sciences, medical and dental research, and for psychiatry.

Biochemical Individuality is a readable book, full of interesting information. Data concerning human variability in anatomical, physiological, biochemical (composition of fluids and tissues, enzymic patterns, endocrine activities, excretion) and pharmacological characteristics are given and analyzed. It is possible that not all the variations considered will be strictly genetically controlled but this will not detract from the general validity of the argument. There is no doubt about the potential salutary effect on medical progress of the emphasis on individual differences.

It is clear that in this type of book the theoretical development of the argument is more important that the details of the factual material. However, it is felt by this reviewer that some loose statements, such as the one on page 49 concerning the estimation of the "intracellular" water, could have been avoided. Individuals differ markedly in their gross body composition. This information, much of which was accumulated in the last 10 years, deserves perhaps more attention in considerations of the extent and significance of differences between individuals than has been given it by the author.

FRANCISCO GRANDE

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Minneapolis, Minnesota

Physiological Psychology. By M. A. Wenger, F. N. Jones and M. H. Jones. viii + 472 pp. Henry Holt, New York, 1956. $6.00.

Life Stress and Essential Hypertension: A Study of the Circulatory Adjustments in Man. By Stewart Wolf, Philippe V. Cardon, Edward M. Shepard, and Harold G. Wolff. ix + 253 pp. Williams and Wilkins, Baltimore, 1955. $7.50.

In many respects the two volumes are very different, the one being an introductory textbook, the other a monograph. Yet, their points of view complement each other. Wenger *et al.* stress that psychology is fundamentally a biological science and they present psychobiology (psychophysiology) as a cornerstone of the science of behavior. The largest amount of space is devoted to well established physiological facts concerning nervous function, hormones, special senses, motion and complex (integrated) behavior. The more "psychological" topics include learning, motivation and emotion. The interactions between mental (cortical) activity and other bodily functions are considered under the headings of somatopsychics (psychological effects of somatic factors) and psychosomatics (psychogenic changes in somatic functions).

Emotion is viewed broadly (probably too broadly) as visceral action, as activity and reactivity of the tissues and organs innervated by the autonomic nervous system which may involve, but does not necessarily involve, skeletal muscular responses or mental activity (p. 343). According to the authors' definition, exercise would also be classified as emotion, since it involves altered activity of the autonomic nervous system.

The final chapter is devoted to problems considered as important targets of research. Many of these are largely the concern of the physiologist. The true realm of psychophysiology, in the reviewer's opinion, is defined by the interaction between physicochemical processes in the organism and behavior. The authors define psychophysiology in broader terms but they, too, believe that many fundamental problems in the study of behavior will not be solved until a "meeting of minds," trained both in biochemistry (and physiology) and in psychology, will take place.

Wolf *et al.* brought together the results of some 10 years of study on circulatory adjustments to varying life experiences. The investigations were carried out for the most part in a special clinic of the

Cornell University Medical College. The course of events in the patients' day-to-day life, their changing attitudes and reactions were examined in reference to the occurrence of symptoms of cardiovascular disturbances. The "stress interview," in which emotionally charged topics were introduced into the conversation while alterations in cardiovascular function were being recorded, served as means for bringing up meaningful, especially threatening, life situations for experimental study.

Reduction of exercise tolerance, evaluated in terms of pulse rate as well as ballistocardiographic and electrocardiographic criteria, was noted in patients with neurocirculatory asthenia during situations provocative of anxiety or anger. Circulatory adjustments involving rhythm of the heart and peripheral blood vessels were examined but the studies were focussed on sustained elevation of blood pressure, without coming to definitive conclusions regarding the role of stress in the pathogenesis of essential hypertension. Nevertheless, the authors believe that the available evidence warrants clinicians' interest in the background, life experiences and attitudes of the patient with essential hypertension and the effort to help him to make a more adequate personal adjustment. In summary, "Not only may the hemodynamic changes characteristic of hypertension, including a reduction in renal blood flow, be induced for short periods in suitably susceptible persons by the contemplation of stressful life experiences, but long-term variations in blood pressure level have been repeatedly correlated with periods of stress. Moreover, the data indicate that the course of essential hypertension may be mitigated by measures directed at enhancing the satisfactions and improving the adjustment of the individual."

The pressor mechanisms accounting for essential hypertension remain obscure. It is suggested that the initial response to emotional stress may provoke renal ischemia which may in turn set off humoral mechanisms which cause ultimately irreversible tissue damage. In reference to personality, the hypertensive patients were characterized as "inclined to be tentative and wary, fundamentally driving and often hostile but unable fully to commit or assert themselves." Encouragement of a freer, more fearless self-assertion and of wholehearted commitments was recommended as a part of therapy.

The data are presented largely in the form of case studies, using numerous quantitative criteria of cardiovascular function. Rigorous experimental studies of the effects of life stress are difficult and the authors are properly cautious in their conclusions concerning etiology and treatment of essential hypertension. However, the profound effects of actual or symbolically represented "stressful" events were documented amply and convincingly.

The description of the cardiovascular effects of emotional stresses has been quite elaborate, and the characterization of the responses leaves little to be desired. The segment which may profitably receive emphasis in future research is the nervous system itself (encephalogram under normal conditions, motor and sensory chronaxies, and other physiological indicators of functional status) and the responses to controlled physiological stimuli (such as direct and conditioned vascular reflexes to heat and cold, or changes in the electroencephalogram under conditions of physiological stress). Dr. E. Simonson, of this Laboratory, pointed out to the reviewer the surprising scarcity in this country of neurophysiologically oriented studies on alterations in the nervous function in man, especially during the initial phase of essential hypertension. Useful and more detailed information on function changes in the central and autonomic nervous system could be obtained in animals with certain types of experimentally induced hypertension.

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BOOK NOTICES

AN INTRODUCTION TO CYBERNETICS. By W. Ross Ashby. ix + 295 pp. John Wiley, New York, 1956. $6.50. Directed to workers in biological and behavioral sciences, the book "starts from commonplace and well-understood concepts, and proceeds, step by step, to show how these concepts can be made exact, and how they can be developed until they lead into such subjects as feedback, stability, regulation, ultrastability, information, coding, noise, and other cybernetic topics."

ANTHROPOLOGISCHER ANZEIGER, Vol. 20. Edited by W. Gieseler and E. Breitinger. E. Schweizerbart, Stuttgart, 1956. Revived after a period of some 12 years, this useful journal continues the tradition of publishing detailed bibliographies, reviews, brief original papers and news, including obituaries.

PROGRESS IN NUCLEAR ENERGY, SERIES SEVEN: MEDICAL SCIENCES, Vol. I. Edited by J. C. Bugher, J. Coursaget, and J. F. Loutit. xii + 165 pp. McGraw-Hill, New York, 1956. $6.00. The use of tracer techniques in the study of the workings of the body was described in a volume published in series VI (Biological Sciences) of this comprehensive survey. The present publication deals with problems of medical diagnosis, investigation of disease processes, therapy, safety, and the determination of absorbed doses of radiation.

WEST HIGHLAND SURVEY. Edited by F. Fraser Darling. xvi + 438 pp. Oxford University Press, New York, 1955. $4.80. A detailed account of a comprehensive social and biological investigation of an area of Scotland suffering from depopulation and economic decline. Eighty pages are devoted to population study.

THE STRESS OF LIFE. By Hans Selye. xvi + 324 pp. McGraw-Hill, New York, 1956. $5.95. A readable presentation of the concept of "stress" (the common denominator of adaptive reactions in the body), its mechanisms in health and disease, and its theoretical as well as practical (medical, psychosomatic, philosophical) implications.

PHYSICS, PSYCHOLOGY, AND MEDICINE. By J. H. Woodger. x + 145 pp. Cambridge University Press, 1956. $1.75. The essays are focussed on the neglect of psychology in medical curriculum, ascribed to the enormous success and consequent prestige of the physical sciences. Special attention is given to the linguistic apparatus of medical psychology.

CHILD DEVELOPMENT. By Elizabeth B. Hurlock. xvi + 703 pp. McGraw-Hill, New York, 1956. $6.00. Third edition, revised and largely rewritten. The presentation of the history of child psychology was replaced by a chapter on social adjustment. Contains a chapter on physical growth. Large bibliography (80 pp., alphabetic). Lists visual aids. Correlated with films.

THE BIOLOGY OF SENESCENCE. By Alex Comfort. xiii + 257 pp. Rinehart and Co., New York, 1956. $4.00. A survey of literature (over 800 references) concerned with the nature and criteria of senescence in animals, longevity and inheritance of life span, growth and senescence, and the role of cellular and endocrinological changes. Man is considered, for the most part, only incidentally.

MAN, CULTURE, AND SOCIETY. Edited by Harry L. Shapiro. xiii + 380 pp. Oxford University Press, New York, 1956. $7.50. A presentation of basic anthropology for the general reader or the beginning student. The book consists of 16 chapters contributed by outstanding scholars. "Human Beginnings" is the only chapter concerned with physical anthropology.

STUDIES IN TOPECTOMY. Edited by Nolan Lewis, Carney Landis, and H. E. King. vii + 248 pp. Grune and Stratton, New York, 1956. A series of studies designed to explore the potentialities of psychosurgical methods as a therapy for mental disorders, and to investigate the role of the frontal lobes of the brain in human behavior. Covers the whole spectrum of problems, from surgical procedures to physiological, psychological, and psychiatric effects and social adjustment.

THE HAZARDS TO MEN IN SHIPS LOST AT SEA, 1940-44. By R. A. McCance, C. C. Ungley, J. W. L. Crosfill, and E. M. Widdowson. v + 44 pp. Her Majesty's Stationery Office, London, 1956. $.60. Summarizes data obtained from men who survived the loss of their ships. Cold appears to be "the greatest hazard facing men adrift in open boats. Lack of fresh water became an important cause of death on the longer voyages, and the effects of drinking seawater seem to have been almost invariably disastrous."

LYSERGIC ACID DIETHYLAMIDE AND MESCALINE IN EXPERIMENTAL PSYCHIATRY. Edited by Louis Cholden. xi + 85 pp. Grune and Stratton, New York, 1956. $3.00. Proceedings of a roundtable conference held at the annual meeting of the American Psychiatric Association. The setting was described by the editor: "The key to understanding psychiatry's deepest mystery, schizophrenia, might lie in the production of an experimental, predictable, controllable, reproducible state—an artificial psychosis. Such are the hopes that some investigators hold for the state of mind induced by giving lysergic acid diethylamide (LSD)."

WORK, WORKERS, AND WORK MEASUREMENT. By Adam Abruzzi. xvi + 318 pp. Columbia University Press, New York, 1956. $7.50. A fresh presentation of the human aspects of industrial engineering, with standardization and production rates as the focal concepts. Problems of fatigue are considered briefly.

LEARNING AND INSTINCT IN ANIMALS. By W. H. Thorpe. viii + 491 pp. Harvard University Press, Cambridge, Mass., 1956. $10.00. Attempts to provide a synthesis of studies on instinct and learning. Different types of learining are discussed and the learning abilities of the main animal groups are surveyed. One of the major objectives of the book has been "to point out to psychologists and learning theorists on the one hand and to zoologists and physiologists on the other how dependent each is, or ought to be, on the work and viewpoint of the other."

THE FUTURE OF ARID LANDS. Edited by Gilbert F. White. ix + 453 pp. American Association for the Advancement of Science, Washington, D. C., 1956. $6.75. Thirty-odd papers plus recommendations from international arid-lands meetings. A multidisciplinary effort to assess the present state of man's struggle to make productive use of large areas of the world characterized by meager or undependable rainfall.

STATISTICS, A NEW APPROACH. By W. Allen Wallis and Harry V. Roberts. xxxviii + 646 pp. Free Press, Glencoe, Illinois, 1956. $6.00. Statistics is defined as "a body of methods for making wise decisions in the face of uncertainty." Intended as a textbook for beginners, it will be found helpful and refreshing. Hear ye, hear ye: "Sometimes authors are so intrigued by tests of significance that they fail to state the actual *amount* of the effect, much less to appraise its practical importance."

PROCEEDINGS OF THE WORLD POPULATION CONFERENCE, 1954. iv + 276 pp. United Nations Department of Economic and Social Affairs, New York, 1955. The meetings were held in Rome under the auspices of the United Nations. The papers presented at the conferences were published in 6 volumes. The Summary Report describes the organization of the conference and its program and presents summaries of the 32 meetings.

POPULATION GENETICS: THE NATURE AND CAUSES OF GENETIC VARIABILITY IN POPULATIONS. Cold Spring Harbor Symposia on Quantitative Biology, Volume 20. xvi + 346 pp. Biological Laboratory, Cold Spring Harbor, New York. $8.00. The primary objective of this important symposium was to bring together the evolutionary and the agricultural geneticists in an effort to establish agreement on fundamental concepts. Of special interest is T. Dobzhansky's introductory review, the sections on general population genetics theory and on quantitative genetics, and A. C. Allison's chapter on some aspects of polymorphism in man.

BODY MEASUREMENTS AND HUMAN NUTRITION. Edited by Josef Brožek. Wayne University Press, 1956. v + 167 pp. $3.50. A reprint, with the addition of editor's preface and an index, of the proceedings of the Conference on the Role of Body Measurements in the Evaluation of Human Nutrition, sponsored by the Committee on Nutritional Anthropometry, Food and Nutrition Board, National Research Council, and held at Harvard University, Cambridge, Massachusetts, June 17 and 18, 1955. The proceedings were originally published in the May, 1956 issue of *Human Biology* (Vol. 28, No. 2).

JOSEF BROŽEK

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INFORMATION FOR CONTRIBUTORS

HUMAN BIOLOGY, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of 8½ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne State University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

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References in the text to the literature should be made by using the author's name followed by the year of publication: " Studies of Garn and Saalberg ('53) . . ." At the end of the article, under the heading " LITERATURE CITED," full references with titles and inclusive page references should appear (double spaced) in alphabetical order of the authors' names: " GARN, S. M. AND J. H. SAALBERG 1953 Sex and age differences in the composition of the adult leg. Human Biol., *25:* 144-153."

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Human Biology

a record of research

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THE STATUS OF PHYSICAL TYPES

BY W. H. HAMMOND

Ministry of Health, London

THE present paper is concerned firstly with the general problem of body types as a form of classification and secondly with a comparison of two present-day type systems; somatotypes and factorial types.

It is necessary to consider the general question of types in relation to classifying individuals since many of the criticisms of somatotypes and factorial types could really be directed against any form of classification.

In the first place we have to employ some form of classification of human beings as also of human attributes, in order to understand them and even more to communicate our knowledge. We group particular items of conduct under labels—aggressiveness, anger, and so on—knowing that different individuals' manifestations of any emotion will differ slightly but will nevertheless be more alike than those of any emotion to which we give another name, and similarly physical characteristics such as chest girth have somewhat different constituent arcs in different people, yet we treat them as though they were uniform. In statistical terms the within-group variation (*i. e.*, trait) is less than the between-group variation. Just as a pattern of activity units, when

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sufficiently coherent, constitutes a trait, so the traits shown by persons can be associated into wider and wider patterns finally covering the whole person when they become known as types. The type, therefore, is also the recognized pattern of characteristics which is rarely if ever the same for two persons yet which nevertheless has such family resemblance between certain individuals and not others that we can speak of the individuals as belonging to the same or different types.

The problem of conformity is the central one of type study and this is necessarily so, since types imply degrees of variation of their individual characteristics and not discreet changes as in species, and also because the characteristics themselves are not in any way unique. The usual methods of overcoming these difficulties are either to set limits within which the majority of characteristics must lie in order to belong to the type or else to regard the types as hypothetical pure patterns to which individuals approximate more or less closely. We then recognize intertypes in the one case or mixed types in the other.

Pure examples of types may be so rare as to be hypothetical and, therefore, the validity of a type classification should not be judged by whether individuals are distributed in discontinuous clusters round the type value or not but by the way in which they give logical coherence to a wide variety of aspects in individuals.

Although pure or extreme types are rare it is easier to understand types if they are described in terms of these extremes. Thorndike ('13) however is emphatically against this and claims that there is only one type, the mediocre and, in the sense that this is the most frequently occurring condition, this is true. Nevertheless, we are accustomed to referring to qualities by their extremes, as, for example, tallness and shortness, the average having no name. However, a more serious disadvantage is that when a complex set of qualities contributes to a type it is quite difficult to say which characteristics can be grouped into one continuum. This indeed is a major feature of types, for although tallness and shortness are opposites in height it is unusual to refer to tall or short types. Types imply different aspects which are not invariable or logical opposites nor yet completely related and they usually embrace a wide sphere, the whole of which may not be made explicit, much less be measured. It is relatively simple to classify persons in each of a variety of measurements separately, indicating whether a person is above or below the average and by how much. The difficulty is that there are so many possible measurements that to describe a person in terms of some of them only gives a very incomplete picture—or if many are used the description becomes hopelessly unwieldy. Even if assignment of a plus or minus sign to some 50 different body measurements could give a fairly adequate description of an individual's physique, there would be 2^{50} classes if all combinations were possible enough to provide a unique class for every individual of the human race. The procedure would, however, have no value, for the usefulness of any classification is in proportion to the reduction of categories (consistent with homogeneity within them) required to characterize the maximum number of individuals in the largest number of aspects. Moreover, merely to add separate values is not very useful since two scores might be the same yet be made up in entirely different ways and the individuals having them might be totally unlike each other.

We obviously need to make a selection of characteristics which are in some way representative of a much wider number, and Type is the term for such a collection of qualities when it affects the whole of the individual or at least most of his physical or mental attributes. If we could obtain a limited number of qualities each having wider representativeness without overlapping they would be ideal to use in classifying individuals. 'Representativeness' is really the quality of forming part of a whole or group and to measure it we need to use one of the accepted methods of studying relations between qualities.

In physical measurements we usually acept the natural boundaries—arms, legs, trunk, and so on—and use one or two measurements out of an infinity of possible ones to represent their major dimensions of length, breadth or girth. These measurements are then correlated or co-variated, so determining their wider groupings, and the individuals who excel in the established groupings of measurements constitute the types. The selection can be further refined by employing multiple correlations which not only take account of the measurements which have the highest individual correlations with other aspects but also the maximum combined relation (through allowing for their own duplication with each other). These fairly straightforward methods at least should be applied to the study of the measurements chosen to measure types. Analysis of variance and discriminant function analysis offer more refined techniques. The chief difficulty of these methods is that they all require some outside criterion of the types and to this extent they involve a circular argument. Factor analysis is a device for determining the broad groupings of characteristics, whilst at the same time giving a method of determining the relations between individual variables and these groupings. Theoretically, therefore, this appears to be a most promising approach to type study. Alternatively, we can compare and group individuals directly according to the pattern of their measurements, *e. g.*, according to whether their girth measurements are large or small relative to their own length and so on (in Burt's ('37) phrase we correlate traits or persons, or in American terms we use direct or inverse analyses). In one case we classify together the individuals who have small inter-individual variations in their measurements and in the other case we group the individuals whose intra-individual variation of measurements is similar. However, the process of classifying may not be explicit in this way nor be based on objective measurements; it may follow the more traditional methods of observation and subjective appraisal by general impression.

A brief historical survey will show how the methods of type study have developed. The first recorded use of types is that of Hippocrates who, over 2,000 years ago, observed a particular body form to be associated with a tendency towards lung diseases, the *phthisic* habitus and opposed to it the *apoplectic* habitus with its own temperament and disease liability. Similar types have been shown in the present century in Draper's gall bladder and ulcer constitutions. Humoral types then flourished in the Middle Ages when methods of study of human beings consisted more of philosophical constructions than that of practice field studies. The melancholic, sanguine, phlegmatic and choleric types were supposedly due to the presence of "black bile," blood, phlegm and yellow bile, in some respects foreshadowing the present endocrine disease groups due to over- or under-production of hormones. The purpose of these theoretical concepts was rather to organize people's understanding than to increase the sphere of knowledge, which is the principal aim of present-day experimental techniques.

Since these types were essentially personal systematizations of broad similarities between characteristics which were in themselves generally known, it is not surprising that different type classifications should arise during the centuries, depending upon the extent of the observer's penetration of thought and also on the interests of the times.

In the early 19th century a further resurrection of types occurred in the French *digestif*, *musculaire*, and *cerebral* types to which the type *respiratoire* was later added, and a somewhat similar manifestation ocurred in faculty psychology.

After a period during which mental faculties came into disrepute and physical types were little heard of outside Italy a resurgence occurred in the field of anthropology in the form of race types. At the same time, in psychology Jung's introverts and extroverts and in psychiatry Krestchmer's pyknic, athletic and asthenic types re-awakened interest in type classifications and for the first time they brought a quite new interest in their train, a stimulus to practical research work. These types, in common with all previous ones, represented hypothetically pure manifestations which may never be realized in any one individual. The pure types began to be used as reference frames for charting human beings who, in the case of race types, were classified as mixtures of pure ethnic groups, whilst the psychological types became tendencies possessed in different degrees by individuals.

The problem of measuring the type tendencies now occupied an entirely new importance and this placed a new emphasis on the elements constituting the type rather than on their wholeness. Thus different racial characteristics such as head or face shape were measured, and questionnaire assessments and, in some cases, tests were employed to measure general characteristics which were supposedly diagnostic of the personality types. At the same time the types themselves were characterized more rigorously than was possible before. Kretschmer's ('25) studies gave a new synthetic approach in which physical types were associated with mental dispositions mainly, in the beginning, through the relations between extremes. The cyclic mental diseases (manic depressive psychoses) were associated with pyknic (rotund) build and schizophrenia with asthenic (lean-slight) build. This association with physical types was then extended to less extreme cases, cycloid and schizoid tendencies, and to the cyclothymes and schizothymes of the normal personality range.

The genesis of the two modern type systems, somatotypes and factor types can be related to the traditional types; Sheldon's ('40) Somatotypes, inspired largely by Kretschmer's types, are logical descendants of types as pure patterns. On the other hand factor types arose very differently. They sprang from Spearman's ('27) attempts to account for the varying relations between charactertistics in terms of factors or 'causes' which were common to them all or specific to any one. From the extension of this to include only part of the correlations of a table, followers of Spearman provided the basis of present day body types. In the beginning the nature of the physical types was incidental to the use of body measurements as material for demonstrating the different factorial methods, the chief advantage of using physical measurements being that the mathematical constants of the analyses could readily be equated to physical attributes which would make them clear to non-mathematical readers and also suggest new techniques to the factorists themselves. Kretschmer's and Sheldon's types, therefore, arose from directly comparing individuals (in Kretschmer's case mental patients with different forms of insanity) and measuring their characteristics, whilst factor types were based originally on comparing characteristics and not persons. The chief difference between factor types and previous attempts at type study was that the factorists initially had no pre-conceived ideas of what types might exist; that is, the data were to demonstrate whatever groupings or clustering of characters might be present. However, it is true that more recently different methods of analysis have been developed and these have to some extent governed the kind of types which result. In particular they have determined whether the groupings of traits correspond to a co-ordinate classification (group factor analyses) or a super- and sub-ordinate classification (bipolar general factor analyses).

Having considered methods of type study in general we can now consider in greater detail the two main type systems of the present day, somatotypes and factor types, and show how far they are alike or different from each other.

Somatotypes.

Sheldon's somatotypes, named endomorphs, mesomorphs and ectomorphs from the predominance of structures derived from the three embryonic tissues, endoderm, mesoderm and ectoderm, respectively, are obtained from photographs taken in the nude from front, side and back with the body posed in standard positions. Originally the typing was done visually without reference to measurements and it was based in the beginning upon a subjective general impression similar to that by which the earlier classical types were postulated. Measuring techniques, which it is hoped will eventually replace the 'scopic' method, are being developed along with refinements of the rating procedures (especially by Tanner ('49) in England and Dupertuis ('50) in America).

The subjective nature of somatotypes has its disadvantages but certain advantages are claimed for it. A skilled observer can make use of the subtler distinctions of body outline which are not amenable to measurement. For example, the body contours can show where a person who is now thin was once fatter and this might indicate (on the somatotyping basis which seeks to assess fundamental characteristics and not the momentary conformation of measurements) that the true rating would be more endomorphic and less ectomorphic than would be inferred from measurements alone. The characteristics of the somatotypes are considered to be all embracing so that no physical characteristic can be neutral to or outside this continuum. A person's hip, arm, chest, etc., are characteristic of one or other of the three types and hence contribute to the score for that type. They are never considered to be without effect and the most can happen is for an individual to be dysplastic or to have aspects which follow one type in one part of the body and a different type in another part, *e.g.*, shoulder and trunk may be endomorphic and legs or arms ectomorphic. The three components were recognized as inadequate to cover all aspects of physique, hence another modality, the degree of bisexuality or gynandromorphy which can affect physique independently of the three somatotypes was also introduced.

There is no mention of general size since the 'scopic' method is concerned with relative shape and the measurements are always expressed in relation to height.

The system is not yet applicable to children because standardized rating procedures are not available for these ages.

A high association is claimed between endomorph, mesomorph, and ectomorph body form respectively and the three temperamental types, visceratonia (relaxed, comfort-loving, tolerant, needing affection and others' company), somatotonia (assertive, physically active, direct in manner, callous, noisy), cerebrotonia (restrained, taut, liking privacy—especially when in difficulty, unsociable and having unpredictable attitudes). The system of scoring for the temperamental types is similar to that for somatotypes, Sheldon ('42).

The main defect of Sheldon's system is that the somatotypes are basically subjectively determined and no measurement procedures will alter this unless the types themselves are modified as a result. The method of equal-appearing intervals should obviously be abandoned when the elements constituting the types are made explicit. A second related difficulty is that the scale intervals 1-7 (or half units if these are employed) may not represent additive units as in an extensive magnitude and this limits statistical manipulation. This is especially true since the three components are also inter-related in a complex way. The

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distribution of values 1-7 in each component could ordinarily be studied to see whether 4 really represents the mean or not and how far the limitation of the extremes to 1 and 7 may be truncating the distribution, but when these are also based on values found in the other two components this becomes impossible. We can not say whether a particular combination, *e.g.*, a 7 for endomorphy and 3 for ectomorphy does not exist because it is logically impossible in the same way that a 7 for tallness and a 3 for shortness would be impossible or because such an example has not yet been found. Sheldon resorts to an arbitrary limitation: that the components must not total more than 12. The fact that there is a higher negative correlation between endomorphy and ectomorphy than between any other pairing of components is not taken into account.

Logically the somatotyping system and its measurements are somewhat unsatisfactory. To select as components three particular combinations out of a number of complexly inter-related physical qualities without knowing how the separate characteristics contribute to them nor how the components are related, is rather like attempting to give a point's position in a spherical space in terms of the ribs of an umbrella of unknown length set at unknown angles to each other. Obviously, the situation needs tidying up. This can only be done satisfactorily (a) when the separate physical characteristics are measured, (b) their relation studied to see whether they cohere to form groups which correspond to the labels endomorph, mesomorph and ectomorph, (c) the relations between the type groups are studied, and finally when (d) units of type measurement having meaningful intervals are devised, *e.g.*, a difference between 3 and 4 for ectomorphy should be in some way equivalent to a difference between 5 and 6, if only that it selects a similar number of individuals from the total distribution.

The interpretation of types as derived from the three embryological tissues is dubious, particularly in the case of ectomorphs, since their ectodermally derived tissues are not really better developed than in the other types, but it is only that the endodermal and mesodermal structures are less well developed. This is only a secondary criticism of somatotypes, however, and the names could be regarded merely as convenient rather than as indicating a causal basis of the somatotypes.

Factorial types.

There is really no single set of factor types comparable with the somatotypes. Many different workers have set out independently to show the presence of body types from various batteries of measurements using different factorial procedures. (Burt, '37, '44, '47; Cohen, '39; Hammond, '42, '53a and b, '57; Eysenck and Rees, '45; Banks, '47 in England and Carter and Kraus, '36; McCloy, '40; Mullen, '40, Moore and Hsu, '46; Thurstone, '46; Howells, '49, '52; Sills, '50; Heath, '52; and Lorr and Fields, '54 in America.) The basic approach has usually been to calculate correlations or co-variances between measurements and analyze them in terms of general influences or factors which are regarded as accounting for (a) all the correlations or co-variances in the battery (general factors), (b) some of the correlations only (group factors) often superimposed upon a general factor, and (c) unique influences (error or specific factors) which only contribute to the separate measurements and so reduce the correlations with other variables. Any combination of the above factors may be used but the types are usually based on the group factors, direct bipolar contrast factors or on the rotated general factors of simple structure rather than on the first general factor of a centroid analysis. The types then comprise those individuals who excel in any one of the groups of measurements. The factors corresponding to the groupings of measurements are usually independent (in England), but oblique factors or transformed secondary factors are used extensively in America. Having found which measurements go with which the next operation is to measure the strength of the factors so as to give them type scores. These are usually calculated from regression equations for the different factors in terms of the measurements, that is, as weighted sums of measurements of a particular kind. In the case of contrasting types, measurements may give a minus contribution to the total, *e. g.*, ectomorphs or leptosomes will have high values for length growth and low values for girths and conversely for endomorphs or pyknics.

The exception to the above procedure is to correlate persons' patterns of measurements directly with each other and then analyze them to provide groups of similar persons. The characteristics of the type groups, *i. e.*, their trait relations, are then studied. From these Burt ('37) derives a type standard against which any individual's measurements may be correlated to indicate his type conformity score. Howells ('52) determines a type factor measurement from the measurements weighted by the individual's factor saturations, that is, if individuals who have high saturations for the endomorph factor also have large trunk girths, the girths are given high weight in determining the factor measurement, whereas structures in which the extreme types show little difference have little weight.

Factorial studies are as objective as any type investigations so far, the chief limitations being their dependence upon the initial choice of tests or persons studied and the fact that the solutions are not unique. However, the results from any factor analysis procedure can generally be translated into those of any other kind by suitable transformation matrices. The outcome of any analysis does not therefore simply depend upon the form of analysis used, otherwise it might be true to claim that the factorist merely gets out of the analysis what he puts into it.

Although there is no commonly accepted type factor solution equivalent to somatotypes, there is a high measure of agreement between analyses of various batteries of measurements by different investigators. Without exception the English studies find that the major distinction is between growth in length and either breadth or girth growth, depending on which measurements are included in the battery. This is true of European and non-European adults (Burt '44), normal and psychotic subjects (Cohen '39 and Eysenck '45) and also of children down to infancy (Hammond '57). Analyses of the same battery of measurements in different yearly age groups show very high consistency in the factor saturations for the different measurements (Burt and Banks, '47; Hammond '53).

Studies on American adults (McCloy, '40; Mullen, '40; Heath, '52) also confirm this distinction, which is also shown by the analysis of measurements for garments and pattern construction based on American children (Hammond '53a) and infants (Carter and Kraus '36).

Most of the batteries of measurements analyzed were taken from existing studies made for a variety of purposes. In the English studies the methods used necessarily contrasted girths, breadths or other measurements with the lengths. Burt, therefore, uses the non-committal term pachysome or bulky. Yet breadth and girth measurements are themselves distinct and it is necessary to determine whether the girths or breadths are the more fundamentally opposed to lengths, or whether these merely form an antagonistic group only in the sense that something must provide the negative aspect of lengths if these represent positive deviations about a mean. When lengths, breadths and girths are all present it is usual to find the girths more strongly opposed to length in the first factor of a bipolar analysis, after which lengths can be split into trunk and limb lengths and the other body measurements into girths contrasted with breadths. In the case of group or oblique factors the girths again form the most prominent grouping after lengths. Perhaps the critical point is that fat measurements have extremely high saturations with the girth group whilst the breadth measurements appear to be related to girths mainly through their direct contribution to girth measurements taken at the same levels rather than because of any fundamental affinity.

Height, trunk girths and breadths are composite measurements dependent upon growth of different long bones, muscles or fat and Heath ('52) prefers to identify her secondary factors with development of these tissues rather than in terms of the composite measurements. This is a useful interpretation especially as fat measurements taken at different body sites have extremely high intercorrelations and similarly for the long bones. X-ray measurements of different muscles or measurements of girths, adjusted to allow for fat, both suggest a strong group factor for muscle development also.

The description of human beings in terms of factors has its disadvantages, although it approaches more closely to the general requirements of type systems as set out earlier. In the first place, any disadvantages which apply to correlations also apply to factor analysis of them. In the second place the method is based on the interpretation of correlations in terms of the ratio of common elements to total elements. Although this presents no difficulties when applied to single correlation coefficients, when several variables are interpreted in this way there are many different possible models which can be fitted to the observed correlations involving elements of different generality. For example, it is possible to account for a table of correlations in terms of separate groups, each of which overlaps, or in terms of a common factor. Mathematically, the effect is the same but the interpretation in terms of correlated types or a general influence and uncorrelated types gives a quite different emphasis. But if there is no unique factor solution to a given set of correlations at least the various assumptions involved in the different methods are usually made explicit and within these assumptions, they can be checked. However, the effects of sampling errors are not easy to estimate in order to test rigorously the goodness of fit of different solutions.

It is not a necessary condition of factor analysis that the factors produced should be anything more than principles of classification of measurements as they exist at any moment for a particular group of subjects. But their maximum usefulness will only be realized if the factors can be identified with more permanent features. However, the identification of factors with outside causes can also lead to disagreement. In so far as these factors correspond to groupings of measurements from different studies there will naturally be more disagreement between factor types than is the case in somatotypes where the position is equivalent to accepting a particular battery of tests and the factor measurements derived from them as put forward by one investigator.[1]

Another difficulty is that, although the type groupings may be accepted, it is a rather complicated matter to assess the type strength of individuals, especially if the general growth has to be allowed for first.

The relation between somatotypes and factor types.

The methods of factor analysis can be applied to the measurements of somatotypes just as to any other measurements. Several studies have been made to attempt to validate the somatotypes. These consist of correlating the measurements of individuals who have previously been somatotyped by inverted analysis to see whether the grouping factors for persons agree with the somatotyping and then determining the composition of the measurements which differentiate them. The second method is to compare the factor analysis of measurements to see whether they are grouped into ways which are equivalent to the characteristics of the somatotypes. In the first kind of analysis Howells ('52) and Lorr and Fields ('54) agree remarkably closely in the person factors they found. Both agree in regarding the endomorphs and ectomorphs as forming one continuum, the first two oblique factors comparing closely in respect of the mean factor saturations for the somatotype groups (see table 1).

Factor I differentiates between ectomorphs and endomorphs in both cases; Factor II differentiates mesomorphs from endomorphs or ectomorphs. The division in Factor I is more towards the ectomorph end of the scale in Howells' analysis and his second factor compensates by being slightly nearer the endomorph pole.

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[1] There is much to be said for a convention of factorists meeting with the object of recommending standard batteries of physical measurements for assessing varieties of physique. Such standardization would enable different workers who are interested primarily in practical problems to obtain type scores which will at once be simple and permit exact comparisons to be made with the results of others.

Sills ('50) correlated the somatotype ratings as variables along with a number of measurement ratios and also found that ectomorphy was the opposite pole of endomorphy rather than a separate factor. In this case, however, the subjects were not selected initially from extreme somatotypes. In general, the factor analyses fail to substantiate the somatotype groupings as the best solution to the measurement data. It is true that a centroid analysis with orthogonal factors could not possibly agree with Sheldon's threefold correlated somatotype groups. As Tanner ('52) has pointed out, if the ectomorphs coincide with Burt's leptosome factor it should be impossible to find the equivalents of the other types among later orthogonal factors. But in fact, the pachysome pole of the first factor in some batteries does approximate very closely to the endomorphs. However, even where the analyses are based on specially selected extreme somatotypes and the form of analysis is such that the factors could correspond to Sheldon's types they do not agree closely. Two studies (McCloy, '40; and Sills, '50) claim to have isolated a factor omomorphy characterized especially by wide shoulders compared with hips more reminiscent of Kretschmer's athletic type. Howells ('52) concludes that "certain other kinds of differentiation come to light which are now masked by the recognition of endomorphy and ectomorphy as independent components bearing attributes which are not simply negatives of one another" and he likewise questions the concept of dysplasia in view of the "non-Sheldonian kinds of differentiation which are consistently and sensibly organized."

TABLE 1

Factorial analysis of somatotypes

	FACTOR I		FACTOR II	
	MEAN SATURATIONS		MEAN SATURATIONS	
	Howells	Lorr and Fields	Howells	Lorr and Fields
Endomorphs	.84	.80	—.08	—.20
Mesomorphs	.12	—.12	.35	.52
Ectomorphs	—.92	—.73	—.10	—.13

In passing, it seems to me to be a mistake to omit consideration of the general size or general shape factors by selecting individuals to minimize these. The general factor contributes so overwhelmingly to the total variance especially in children, that it has by far the greatest predictive value for all measurements, and the method of comparing individual measurements relative to height as the means of allowing for it, is an unsatisfactory one.

Factor schemes, such as those described, are complicated and highly technical so that they may lose in usefulness what they gain in precision. It is worth while, therefore, to see what simple steps may be taken to produce a workable typing system, making use of the best features of the somatotypes and factor types. Parnell's ('52) use of standard deviations in different measures grouped into muscles, fat or 'leanness' groups is a good basis on which to begin.[2] If we substitute bone length measurements for height/weight (which is a composite of length and absence of muscle or fat) we shall then have three measures of tissues each of which will be equivalent since it is based on standard deviation units.[3] The individual's general size will be indicated by the sign and magnitude of these units. (At present in somatotyping one could have a large or small individual of any given type figure, and the figures give no indication of this). On the proposed scheme the relatively muscular, fat or long types would show in the pattern of the numbers whilst at the same time their 'size' would be indicated by the level of the numbers. For example, a + 7 + 7 + 7 (a possible figure) would be a person who was among the biggest 2 per 10,000 in muscle, fat and length and yet he would be of average proportions—a sort of giant in fact. Similarly, a — 7 — 7 — 7 would be a scaled down individual or dwarf, and 0 · 0 · 0 · would be the individual corresponding to the average measurements in all respects. If we designate the variables, L. M. F. or length, muscularity and fatness, + will represent long, muscular or fat and — short, amuscular or thin. The various combinations would be long-muscular-thin type (+ + —), short-muscular-fat (— + +) and so on. The terms large or small could be used to summarize the figures qualifying them with whatever component did not conform, *e.g.*, the first person above would be a large thin type, the second a large short type, 'large' because both were above average in the majority of measurements. These may be rather unusual sounding designations but in any case verbal labels are unsatisfactory substitutes for figures as we discover at once when we come to describe the different possible combinations in verbal terms. It is because the dividing lines between the terms are ill-defined that labels should only be used as a very rough guide and, in any written work, numerical values should always be given along with the verbal descriptions to define them. Body photographs may still be used to study these types.[4]

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[2] Hooton according to Hunt ('52) uses a similar scheme measuring fat, muscularity and 'attenuation' based on the ponderal index.

[3] Actually further precautions are necessary to allow for the extent to which the particular muscle, fat or long bone measurements are correlated with each other, and the measurements would need to be carefully chosen for each of them to indicate general size as well as its own sub-group.

The above scheme at least has the advantage of using combinations of measurements which conform to established group factors in factorial studies, whilst the calculation of the type scores is much easier than the regression method and at the same time makes a distinction between overall size and type strength. (The predominance of one component could be expressed as the difference between its type and the average, whilst shapeliness—not in the artistic sense—would be the sum of the differences, between paired components 1-2, 2-3, and 1-3.)

As no agreed set of criteria is available for somatotyping children it is especially useful and necessary to arrive at an agreed typing system in this field whilst the position is open. By so doing it would be possible to obtain the great advantage of unanimity which adult somatotyping offers without sacrificing the advantages in respect of objectivity and rigorous treatment offered by factor studies. Even in studying adults it would be well to test the validity of somatotypes by measurements in unselected populations rather than in groups of extreme somatotypes, for if the somatotyping grouping is not confirmed (and these are the indications from the available studies) then substituting measurements for the subjective appraisal of somatotypes would appear to be of dubious value. Another consideration is that children's types will need to be related to those of adults. Children's types have also been found to have a different basis from that of somatotypes, consequently continuity with present adult somatotypes would appear to be impossible.

Are types necessary at all?

So far we have been mainly concerned with the rationale of any assessment of multiple types in order to show how some of the more desirable features could be introduced and substituted for present practices. One might take the more devastating view that any kind of type study is too stultifying to warrant this attention to details. Do types, however well authenticated they may be, help us at all? Pure expression of the types is rarely met with and the majority of individuals are somewhere near the mean. To use type terms is somewhat like describing an average person as being compounded equally of extremes, *e.g.*, of tallness and shortness. Those whose study of types has taken place among extremes tend to regard the normal in these terms whilst others often consider the extremes as pathological conditions constituting distinct phenomena having no connection with the normal. I believe that factorial methods of type study can provide a truer evaluation of the position. They represent (or should represent) a necessary aspect of the statistical study of inter-related variables upon which the study of the complex field of human behavior must at present rely if it is to become a science. The use of trait rating scales as units in psychology may represent a transitional stage until more fundamental behavior units can be discovered. Similarly physical or mental types represent a further stage of generalization but both have their usefulness at different levels of behavior study. Thus if we want to know how a person is likely to perform under a given set of circumstances we can use these circumstances as actual test situations. However, if we know from type study that certain types exhibit a whole series of characteristics, then we need only test or observe a few of these characteristics to be able to predict the others. If in addition to establishing physical types we can say that these are associated with mental characteristics—forming psycho-physical types; then we can extend the process correspondingly—always assuming that the degree of relationship is sufficiently close to afford some improvement in prediction compared with the situation in which the physical types are not known. To test this we need to be able to specify the type adequately and then to study the widest possible influences of the type conformation.

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[4] The types would represent the body conformation at a particular moment without any claim to genetic basis (but see p. 238).

One of the chief objects of such study should be to test how consistent the types are over a number of years, for unless the individual's type make-up has some constancy we can hardly expect it to have any predictive value in other fields. The author's own work on follow-up studies in factor types of children (Hammond '57) indicates that the same kind of types (from attained measurements) can be shown at all ages and growth can also be analyzed into similar type patterns. However, the type constancy is little more than we should expect if a child's type were established very early in life and the subsequent growth were random or neutral to the type. That is, on average, past growth appears to add comparatively little to the predication of the type differentiation. There must necessarily be some type consistency in children because of the contribution which the earlier measurements make to the later ones and as childhood advances this becomes proportionately greater compared with the growth which is capable of upsetting the type. Correlations of an order up to 0.8 are therefore to be expected over a period of two years on this account alone and this is the order of correlation actually found.

There are also immediate objects of study of physical types, such as the relationship between anatomical characteristics and performance in different occupations or sports, in order to use the type as a basis of selection for recommending physical activities in which the individual is most likely to succeed. It may be that incentive is more important than physical build but physique may set limits to what is possible. If one may speculate on this point it is to urge the use of types not so much as an instrument of prediction in themselves, but rather as a preliminary to studying certain of their characteristics more intensively. For example, some physical types appear to be more susceptible to certain diseases than others, yet the relation may be too loose to aid prediction directly. However, the particular individuals of a type having the disease may be characterized by some special aspects of the type syndrome only and these might be made the basis of future prediction.

The main aims of type study should therefore be, firstly, to make the types and their measurements more objective and refined, secondly, to reach general agreement on these types so that further studies will be comparable, and thirdly, to devise simplified methods, such as those suggested, for measuring the type strength.

SUMMARY

The present paper adopts a historical approach to the study of body type and sets out some theoretical requirements for any classification systems and also the special requirements of type as principles of classification exemplified in the two current systems, somatotypes and factor types.

The chief weakness of somatotypes is that the types themselves are arbitrary and complexly related whilst the different measuring scales

have not been studied sufficiently in relation to each other and to the types, and the form of the measurements makes it impossible to construct theoretical distributions for these variables.

Factor types offer no generally agreed solution equivalent to the somatotypes with the advantages of comparability for different investigators, but they have a more objective and theoretically advanced basis although they too are dependent to some extent on the measurements selected and the factor method used. The major physical types agree closely at different ages but the complication of assessing factor types by regression equations presents a serious difficulty in popularizing factorial methods.

A compromise type procedure is proposed (especially for use with children where somatotyping is not yet possible). Three components, length, muscle and fat are measured in standard deviation units as in Parnell's scheme and expressed by positive and negative numbers whose magnitude indicates general size and whose pattern shows the type distinction. The scheme would be based on direct anthropometry supplemented by photographs were possible.

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SEX DETERMINATION FROM THE SKELETON

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SEX, unlike most phenotypic features in which man varies, is not continuously variable but is expressed in a clear bimodal distribution. This bimodality, or polymorphism, is determined and maintained by the inherent nature of man's genetic-reproductive mechanism. In this respect it is dissimilar to most other polymorphic traits, such as the allelic varieties of a blood type, which are primarily maintained by genetic equilibrium and/or the balance of selective mechanisms. But sexual dimorphism is similar to other expressions of polymorphism to the extent that clearly defined, genetically determined forms, or phases, of the same species co-exist in single breeding populations. Similarity also exists in terms of classification; in both sexual and other polymorphic variability clear categories exist. Ambiguous forms are non-existent or exceedingly rare since the phenotype is a clear expression of the genetic determinants.

In the problem of determining the sex of the skeleton, it is important to note that the phenotype of sex, while it is an expression of a distinct genotype, is fundamentally different from other kinds of polymorphism on two counts. As previously mentioned, it differs first as a consequence of its being determined by a special genetic-reproductive mechanism which is at the chromosome level and thus involves many genes; and secondly, as a consequence of this, sex differences are expressed in many aspects of the phenotype through widely varying levels of genetic influence. Thus, some features of the phenotype give clear indications of sex while others may be of little or no use.

The extent to which the skeleton, as one part of the gross phenotype, can be employed in determining sex is of interest in physical anthropology. From what is known, it seems clear that three varieties of influences cause sex differences in the skeleton. The first is reproductive function which is primarily expressed in variability in pelvic morphology; secondly, there are genetically influenced contrasts in gross bone size and proportions; and lastly, there are differences in the amount and proportion of body musculature as shown by attachment markings on the bone. These various influences are not always separable in their effects but, in the main, they cause the phenotypic differences in skeletal morphology which demarcate sex.

The determination of sex of skeletons has always been of importance to anthropology. In most archeological investigations a classification by sex is the first step taken in the analysis, and important conclusions about the nature of the group and their culture are based on sex ratios. In studies of human evolution, important questions of relationships depend upon the accuracy with which sex is assigned. While effort is made constantly to improve the accuracy of sorting and the literature is full of references to “hallmarks” of sex which are said to be of value, few investigators know the level of accuracy that they achieve or even should expect from the method or methods they use. While there is no substitute for experience in such matters, it is essential that work be done to establish the levels of accuracy achieved by various methods of sexing.

This paper reports the results of an investigation designed to find the sex discriminating efficiency of several measurements on the post-cranial skeleton, using specimens of known sex. The study was initiated in order to accurately assess the discriminating value of several easily measured features, rather than to find new “hallmarks” of sex in the skeleton. The selection of measurements was based upon the general considerations stated previously. Analysis of data was arranged so that a precise probability statement could be made about the usefulness of the measurements for sexing. The general plan, and summary of the investigation is designed so that it might have the highest practical value for archeology, physical anthropology, and forensic medicine.

The expectation is high that sex can be determined with accuracy if the specimen is adult and complete. If it is immature or incomplete we may be merely guessing with little assurance of being right. The results of this study indicate that the upper limit can exceed 95%. It is up to the experienced investigator to estimate, on the basis of completeness, age, and in light of the particular problem he faces, what the probability of the correct assignment of sex may be.

MATERIALS AND METHODS

Known adult male and female Negro skeletons from the Terry Collection were measured. They were made available for our study through the courtesy of Dr. Mildred Trotter and the Department of Anatomy of the Medical School of Washington University. Support for this study came from the Wenner-Gren Foundation for Anthropological Research to the Laboratory of Physical Anthropology at the University of Michigan. Measurements were taken on the left side of the 99 known male and 101 known female Negro skeletons. The measurements used in the discriminant analysis were as follows:

1. Femur Length (Bicondylar)
2. Femur Head Diameter
3. Humerus Length
4. Epicondylar Width of the Humerus
5. Clavicle Length
6. Ischium Length
7. Pubis Length.

Other measurements taken were: sternum width (measured between the estimated centers of the surfaces of clavicle-sternum articulation) and the lengths of the right clavicle, humerus, and femur. These latter measurements were taken so that right-left long-bone asymmetry could be examined and also shoulder width could be estimated. Inasmuch as females have relatively broader hips and narrower shoulders than males, it was thought that an ischio-clavicle index might have special value for sexing. This did not turn out to be the case as it was of less value than the ischium-pubis index (I/P). The pattern of right-left asymmetry also had no value for sexing, but since it may be of interest, the results are noted. The opening of the sciatic notch was also observed and recorded. Values were assigned according to the degree of opening with the number 1 recorded for the exaggerated male condition and 5 for the extremely open female notch.

All measurements were made by one individual, F.P.T., and the values were punched and verified on IBM cards. Using an IBM electronic calculator, we obtained values useful for comparison and for discriminant analysis. The discriminant function analysis was performed by W. J. S.

The data have been analyzed in three different but related ways.

The first is a measure-by-measure comparison which gives the nature of sex differences for each individual measurement. Visual graphs and standard statistical comparisons are used to report these. Second, a sorting procedure is followed whereby those individuals not separated by the ischium-pubis index method are tested by other methods. Twenty percent of our sample of 200 are not correctly sexed by the ischium-pubis index. When these 40 individuals are examined, other measurements are found which sex up to 95% of these. Last, but most important, a discriminant analysis is performed. With this statistical tool the aggregate values for sex discrimination of all measures taken together or in various combinations can be found. Everyone experienced in problems of sexing the skeleton knows that gross size, evidence of amounts of musculature and pelvic morphology are useful, but while these various indicators of sex are closely correlated they do have a measure of independence. Usually the more signs of sex that are evaluated the higher will be the likelihood of correct determination. It follows that each measure on the average has its own certain independent value and that it is the sum of these values that increases the likelihood. Discriminant analysis leads to the selection of a linear function of these measurements, which has maximum utility for assigning sex to individual specimens. The result is to give a simple formula for determining the sex of any single specimen, and a statement of the probability that sexing is correct for all the specimens in a series.

RESULTS

In figures 1-4, histogram graphs for femur length, femur head diameter, sternum width, epicondylar width of the humerus, clavicle length, humerus length, ischium length and pubis length are given. Figure 5 presents the graphs for ischium-pubis index.

The reader may visually evaluate the patterns of variability expressed in these figures. Of special interest is the fact that for pubis length the mean value for females is absolutely and significantly larger than the male value. While the ischium-pubis index was devised by Schultz ('30) it has been pointed out by others (Washburn, '48, '49, Hanna and Washburn, '53) that the pubis length relative to ischium is of great use in sexing human skeletons. If the measurement of the length of the pubis is divided by some measure which is highly correlated with gross body size, such as femur length, or more conveniently,

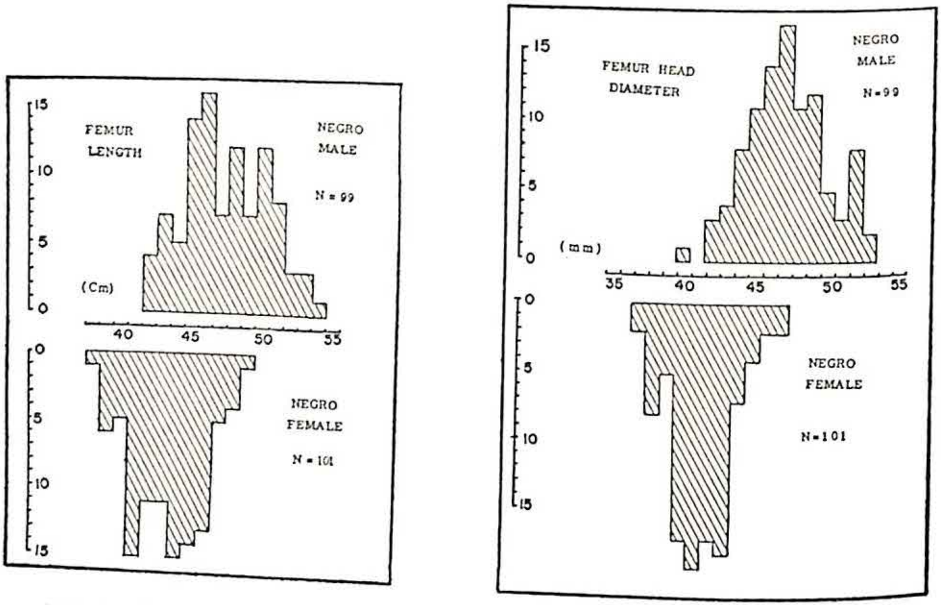

FIG. 1. THE DISTRIBUTION BY SEX OF MEASUREMENTS OF FEMUR LENGTH AND FEMUR HEAD DIAMETER.

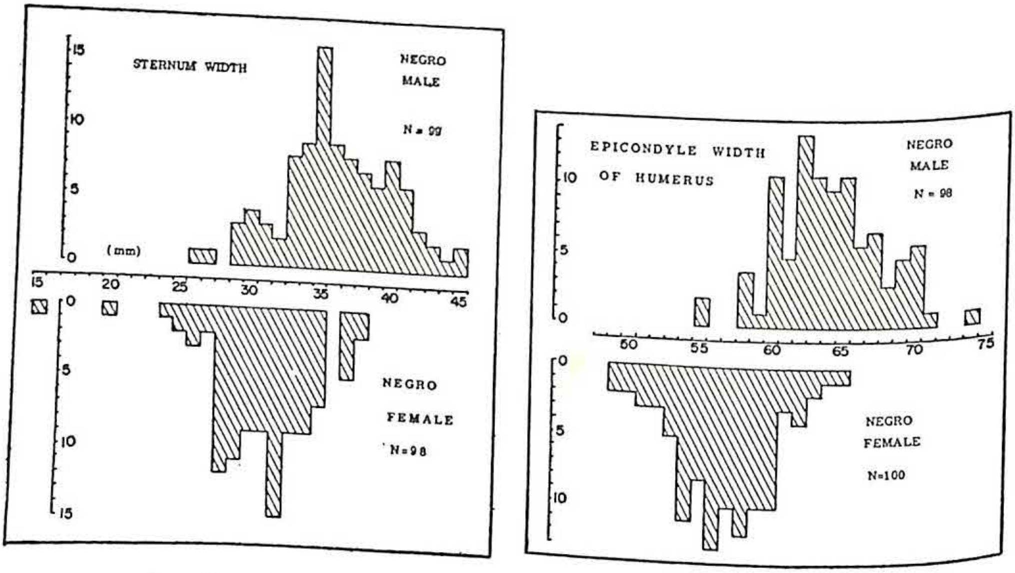

FIG. 2. THE DISTRIBUTION BY SEX OF MEASUREMENTS OF STERNUM WIDTH AND EPICONDYLAR WIDTH OF THE HUMERUS.

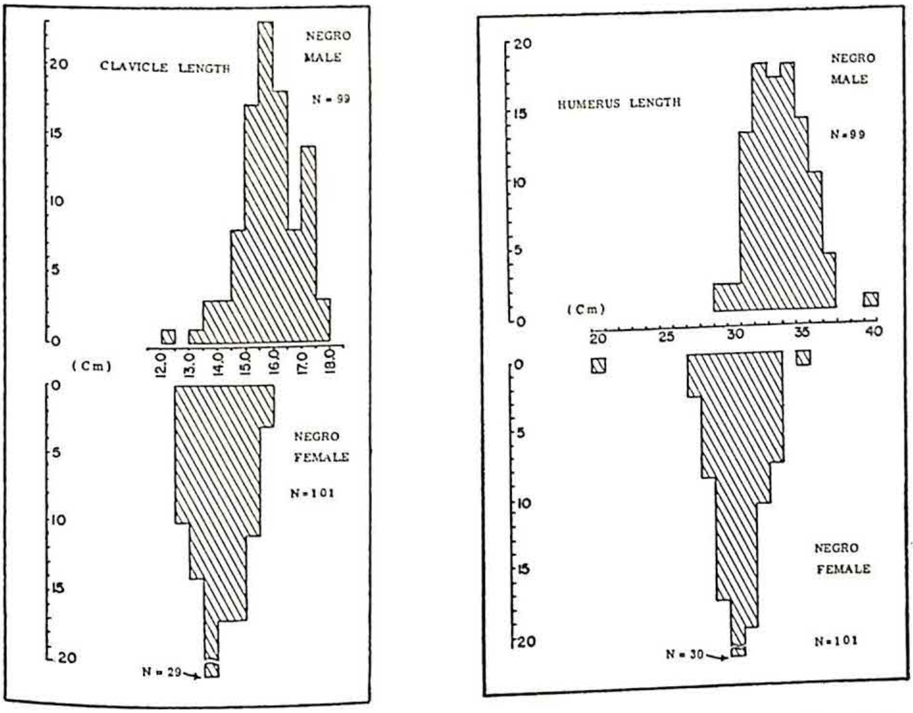

FIG. 3. THE DISTRIBUTION BY SEX OF MEASUREMENTS OF CLAVICLE LENGTH AND HUMERUS LENGTH.

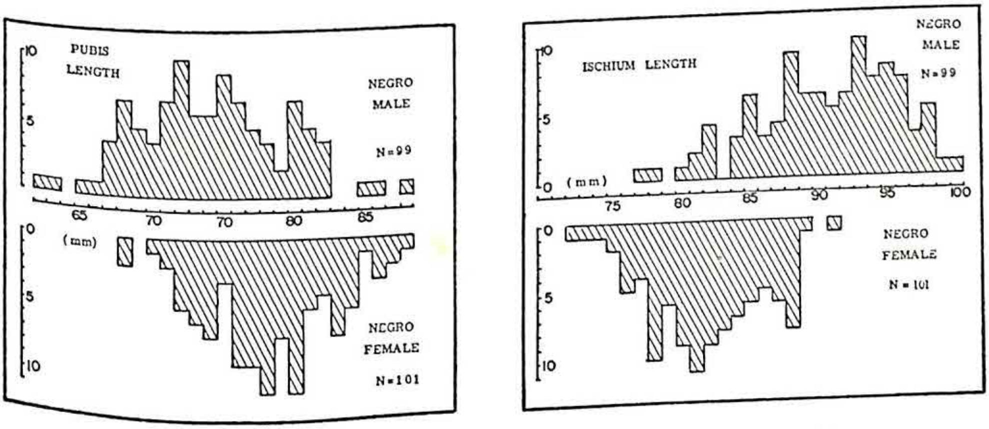

FIG. 4. THE DISTRIBUTION BY SEX OF MEASUREMENTS OF PUBIS LENGTH AND ISCHIUM LENGTH.

the ischium, an index with higher values for females than for males will result.

In table 1, the mean values, standard deviations, standard errors, male to female "t" values and the "differences of logs" for each of the measurements in the series are given. All of the "t" values are highly significant, but they are not the same for each measurement. While sternum width for instance, is relatively the most different (see figure 2) when the means are compared, it varies more widely (see table 1) and thus is less significant because the standard error is relatively large. Pubis length shows a lower value than 6 of the other 7 measurements, but it is unique, as previously mentioned, in that it is the only one in which the female values exceed the male. Of all the measures used in this study femur head diameter is the best single discriminator.

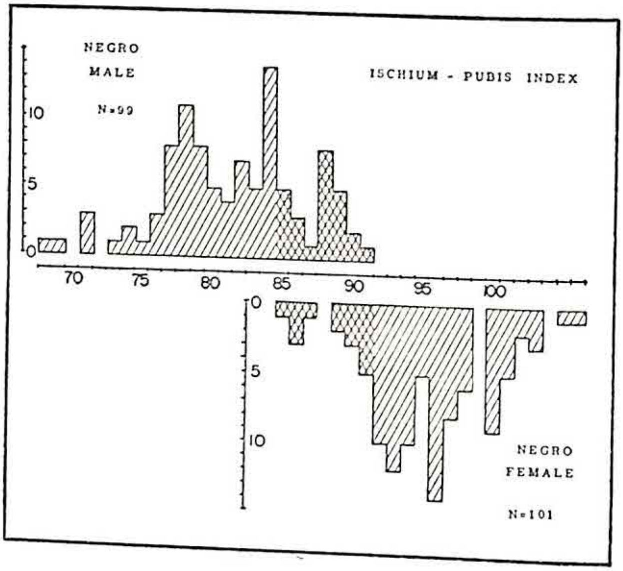

FIG. 5. THE DISTRIBUTION BY SEX OF MEASUREMENTS OF THE ISCHIUM-PUBIS INDEX.

Figure 6 gives a graphic arrangement of the mean values from the data and is designed to point out the levels of relative differences in overall form between the sexes. The method (Simpson, '41) expresses the difference between the logarithms of the means. One of the forms being compared (males) is arbitrarily given a value of zero. The difference between the logarithms of the mean value is plotted in reference to this line. If the two forms are merely different in size but identical in proportions the lines will be parallel. If one is not merely the miniature of the other, however, the lines will not be parallel, but will be dissimilar to the degree that form differs. We see then

TABLE 1

Statistical values by sex for various measurements of the skeletons of American Negroes, and including results of tests of significance of difference between the sexes for each measurement and difference of log

	MEASUREMENT	N	SEX	MEAN (mm)	S.D.	S.E.$_m$	"t"	DIFFERENCE OF LOG
A	Femur length	98	♂	477.34	28.37	2.866	10.13	—.344
		100	♀	439.10	24.55	2.456		
B	Femur Head diam.	98	♂	47.17	2.75	.278	16.17	—.554
		100	♀	41.52	2.12	.212		
C	Humerus length	98	♂	338.98	18.55	1.874	12.51	—.45
		100	♀	305.89	18.66	1.866		
D	Epicondylar width of Humerus	98	♂	63.89	3.59	.363	14.50	—.51
		100	♀	56.76	3.32	.332		
E	Clavicle length	98	♂	158.24	10.06	1.158	13.90	—.52
		100	♀	140.28	7.99	.800		
F	Ischium length	98	♂	90.55	5.06	.511	13.52	—.44
		100	♀	81.80	4.00	.400		
G	Pubis length	98	♂	74.14	5.11	.516	6.39	+.23
		100	♀	78.21	4.34	.434		
	Sternum width	99	♂	36.15	3.91	.393	9.66	—.67
		98	♀	30.96	3.63	.367		

from figure 6 that females are not merely smaller than males, but each measure is relatively different. Consequently, some measurements are bound to be better than others in discriminating for sex.

Figures 1-6, while giving the picture of variation by sex for each of the 8 measurements, do not allow the reader to follow any individual and see his relative position in the scale of variability from graph to graph. *Our problem is to sex the individual and not the measurement.* Short of publishing all the measurements for each individual, few methods will allow this sort of comparison to be made. But in view of the importance of following this point of attack, we give a partial analysis along this line. An examination of figures 1-5 shows that the

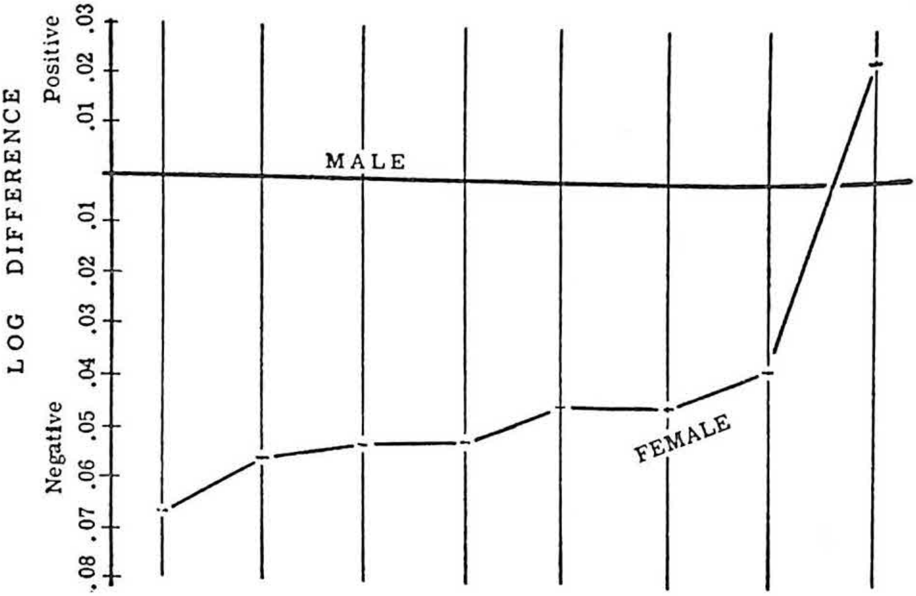

FIG. 6. COMPARISONS OF MALE-FEMALE MEAN VALUES FOR VARIOUS MEASUREMENTS USING THE DIFFERENCE OF LOG METHOD (SIMPSON, '41). The male values are located arbitrarily at 0 so the graph shows the relative difference of females compared to the males in terms of the difference between the logs of the means for each measurement.

ischium-pubis index by itself gives the best sorting. Forty of 200 individuals (20%) are not correctly sorted if we consider all with an index less than 85 to be male and all over 91 to be female (darkly shaded area, figure 5). This leaves 40 individuals not sexed by this single method. In figure 7 these 40 are placed according to their size for the 6 other measurements and sciatic notch opening. The ischium-pubis index is also shown. In addition, a particular symbol is assigned to those individuals who are not sexed by any one measure so that they may be followed to see how they fare in each array. Where the same symbol appears repeatedly it is apparent that for several measure-

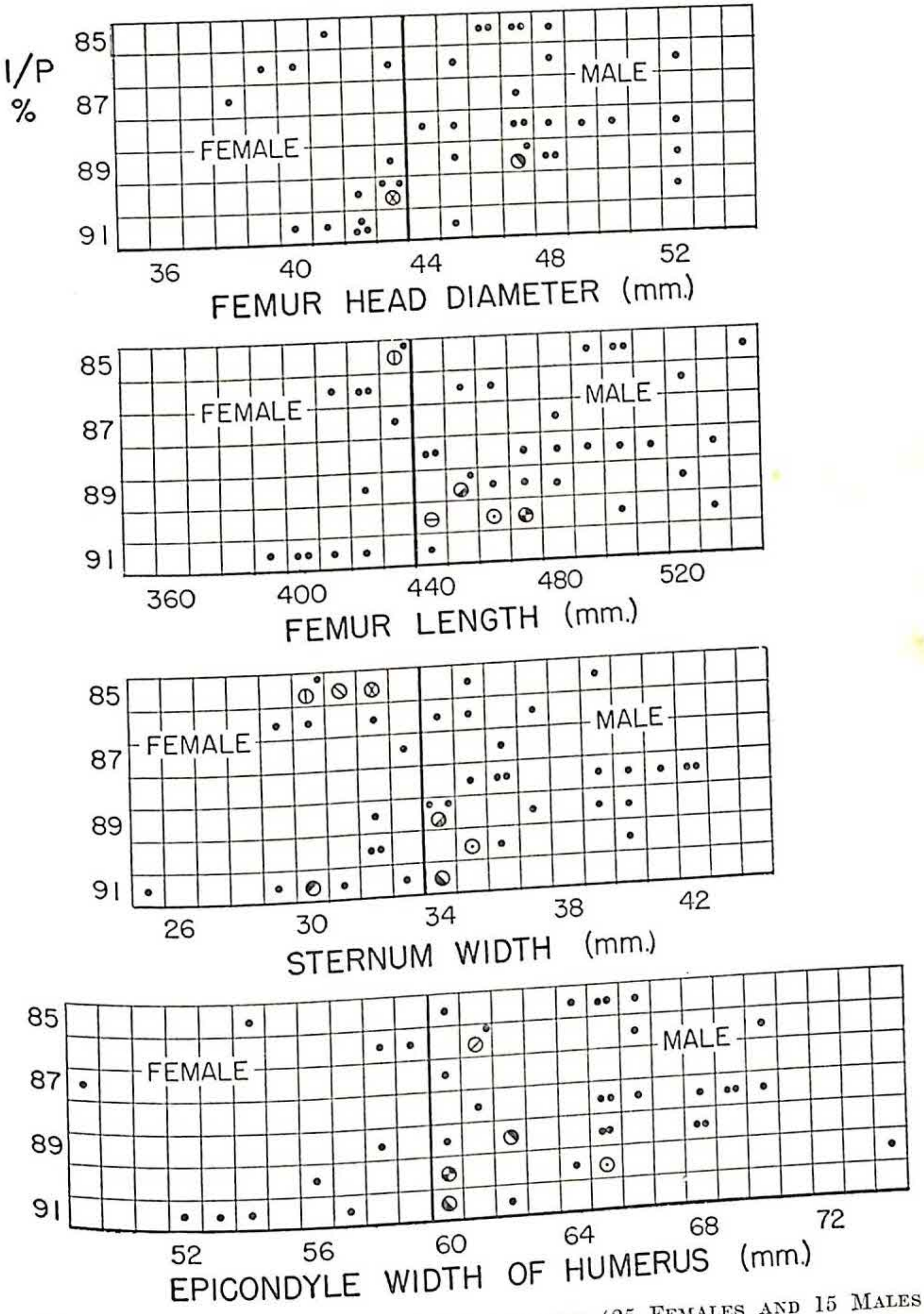

Fig. 7a. The Distribution of 40 Individuals (25 Females and 15 Males Shown in the Darkly Shaded Area of Fig. 5), Whose *I/P* Index is Between 85.0 and 92.0, According to Other Measurements. Each case is indicated with a solid dot if properly located with reference to a heavy vertical line dividing the sexes in each array. The larger symbols denote cases which are not within their sex range. They are individually assigned except that ⊗ denotes all cases which appear out of their proper range only once.

ments that person is out of the expected size range for his sex. This arrangement shows how some individuals who are difficult to sex vary for the different measurements.[1]

The best single discriminating measurement next to the ischium-pubis index is femur head diameter. Only two persons not sexed by ischium-pubis index remain unsorted if a limit value of 44 mm diameter is used, with all under being female and all above being male. The method as presented here cannot be carried one step further, however.

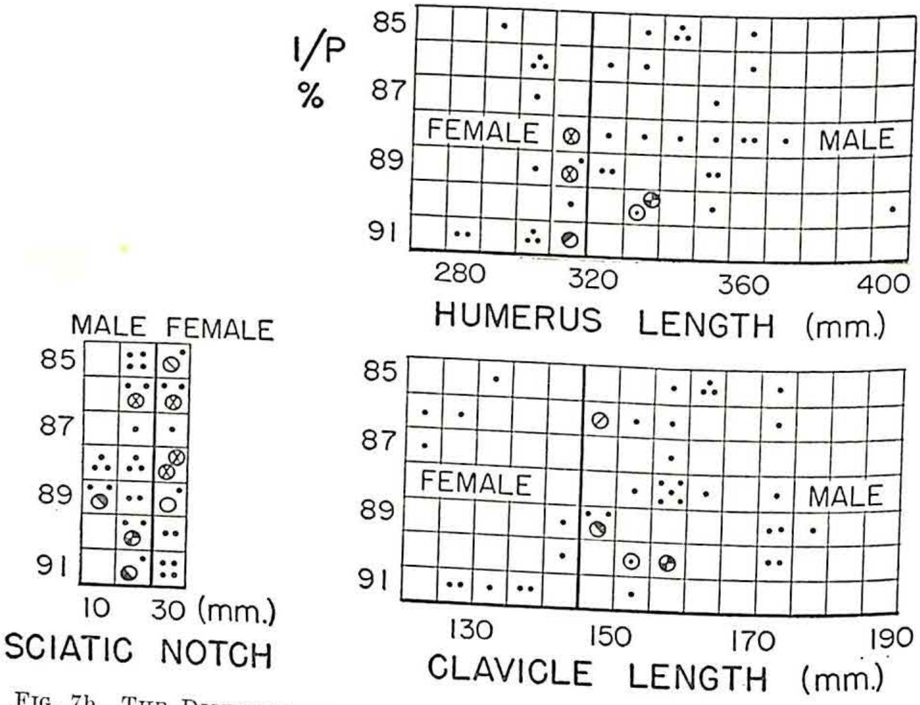

FIG. 7b. THE DISTRIBUTION OF 40 INDIVIDUALS (25 FEMALES AND 15 MALES SHOWN IN THE DARKLY SHADED AREA OF FIG. 5), WHOSE *I/P* INDEX *is* BETWEEN 85.0 AND 92.0, ACCORDING TO OTHER MEASUREMENTS. Each case is indicated with a solid dot if properly located with reference to a heavy vertical line dividing the sexes in each array. The larger symbols denote cases which are not within their sex range. They are individually assigned except that ⊗ denotes all cases which appear out of their proper range only once.

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[1] The symbol ⊗ is used to signify the dimensions of all those individuals who are out of the expected range for their sex in only one of the measurements shown. The other symbols are individually assigned to cases which more than once are out of the range for their sex.

Even though the symbols of the two individuals not sorted by femur head diameter fail to appear in the femur length or humerus length arrays, it does not follow that these two deviant individuals could be picked out of the sample if sex were unknown. Despite this, it is quite accurate to conclude that *in this sample* where sex is known we can sex with 99% accuracy if we first sort for ischium-pubis index, calling all individuals male if under 85.0 mm and all female who are 92.0 or over, and next sort those remaining, calling all under 44 mm for femur head female and all others male. The resulting male-female groups have only one individual per 100 incorrectly sexed. While we can be confident that this formula would probably give high accuracy for any other American Negro population or possibly any Negro population, we do not know the exact level (Thieme, in press).

A discriminant function analysis has been carried out using these data in order to determine the power that all the measures taken together have for discrimination. Discriminant analysis for problems of sexing skeletal material has been used previously (Mukherjee, Rao and Trevor, '55, Pons, '55). Rao applied the method to pre-historic skeleton material of unknown sex and Pons used several measurements on each of two bones, femur and sternum, but did not combine them for both bones to find their cumulative discriminating value. Using four measurements on the femur he found the sexing error to be about 5%, with femur head diameter and bicondylar width contributing most. These two papers, while demonstrating the value of discriminant analysis for sexing, do not show to what degree the method may be useful in multiple measurement analysis from several bones on material of known sex. In addition, while this is a valuable statistical method, it is not well known in physical anthropology. Because of the importance of this method, the following section gives the method involved in discriminant analysis in some detail and is arranged in step-by-step order so that it may have the highest practical value.

DISCRIMINANT ANALYSIS

The basic theory of discriminant analysis was developed by Fisher ('36, '38, '40) in a series of three classic papers. A number of other individuals, notably Mahalanobis ('36) and Rao ('52), have made significant contributions to the theory of parametric discriminatory topology, and recently, Fix and Hodges ('51) have investigated non-parametric discriminant functions. We shall indicate only briefly the argument underlying parametric discriminant functions and then present in detail the computational procedure for constructing a discriminant function of the type to be employed on the present data. A complete presentation will be found in Rao ('52).

Generally the use of a discriminant function arises in the following context: We are given samples of size N_1 and N_2 drawn from two populations each characterized by p variates, and are required to find a linear function, say

$$X = \lambda_1 x_1 + \lambda_2 x_2 + \cdot \cdot \cdot + \lambda_p x_p$$

which will maximize the ratio of the between population to the within population variance of X for the two samples. That is to say, we are required to estimate $\lambda_1, \cdot \cdot \cdot, \lambda_p$ such that the ratio

$$\frac{[N_1 + N_2 - p - 1]}{p} \; \frac{\sum\limits_i N_i(\bar{X}_i - \bar{X})^2}{\sum\limits_{ij} (X_{ij} - \bar{X}_i)^2}$$

is a maximum, where $\bar{X}_i$ = the mean of the linear function in the i^{th} sample (here $i = 1, 2$), $\bar{X}$ = the grand mean of the linear function, and X_{ij} = the value of the linear function for the j^{th} individual in the i^{th} sample, and where $j = 1, \cdot \cdot \cdot, N_i$. The ultimate purpose of this linear function is, in most instances, to form a basis for assigning (classifying) unknown observations to one or the other of the two populations.

To give meaning to this ratio in experimental situations, we make two assumptions, namely, that

(1) each sample was drawn from a p-variate normal population, and

(2) the populations involved have homogeneous, *i. e.*, equal, variance-covariance matrices.

The construction of the discriminant function proceeds as follows (the reader can easily extend the computations to those cases where the variables are more numerous than three):

Step 1. The computation of means, differences between means, and the sum of products of deviations matrix: Available to us are the sums, sums of squares, and sums of cross products for the measurements femur head diameter (B), ischium length (F), and pubis length (G)

for samples of 98 Negro males and 100 Negro females. These values are

Males

$$\begin{array}{lll}
\sum_{♂} B_{♂} = 4623 & \sum_{♂} B_{♂}^2 = 218821 & \sum_{♂} B_{♂}F_{♂} = 419410 \\
\sum_{♂} F_{♂} = 8874 & \sum_{♂} F_{♂}^2 = 806062 & \sum_{♂} B_{♂}G_{♂} = 343423 \\
\sum_{♂} G_{♂} = 7266 & \sum_{♂} G_{♂}^2 = 541282 & \sum_{♂} F_{♂}G_{♂} = 659236
\end{array}$$

Females

$$\begin{array}{lll}
\sum_{♀} B_{♀} = 4152 & \sum_{♀} B_{♀}^2 = 172842 & \sum_{♀} B_{♀}F_{♀} = 340163 \\
\sum_{♀} F_{♀} = 8180 & \sum_{♀} F_{♀}^2 = 670726 & \sum_{♀} B_{♀}G_{♀} = 325158 \\
\sum_{♀} G_{♀} = 7821 & \sum_{♀} G_{♀}^2 = 613561 & \sum_{♀} F_{♀}G_{♀} = 640901
\end{array}$$

where $\sum_{♂}$ and $\sum_{♀}$ indicate that summation is over all males and all females, respectively. We now compute the following quantities for the males:

$$\bar{B}_{♂} = \frac{\Sigma B_{♂}}{N_{♂}} = 47.173469\,; \qquad S_{B♂} = \frac{N_{♂}\Sigma B_{♂}^2 - (\Sigma B_{♂})^2}{N_{♂}} = 738.06\,;$$

$$S_{BF♂} = \frac{N_{♂}\Sigma B_{♂}F_{♂} - (\Sigma B_{♂})(\Sigma F_{♂})}{N_{♂}} = 792.63$$

$$\bar{F}_{♂} = \frac{\Sigma F_{♂}}{N_{♂}} = 90.551020\,; \qquad S_{F♂} = \frac{N_{♂}\Sigma F_{♂}^2 - (\Sigma F_{♂})^2}{N_{♂}} = 2512.24\,;$$

$$S_{BG♂} = \frac{N_{♂}\Sigma B_{♂}G_{♂} - (\Sigma B_{♂})(\Sigma G_{♂})}{N_{♂}} = 660.57$$

$$\bar{G}_{♂} = \frac{\Sigma G_{♂}}{N_{♂}} = 74.142857\,; \qquad S_{G♂} = \frac{N_{♂}\Sigma G_{♂}^2 - (\Sigma G_{♂})^2}{N_{♂}} = 2560.00\,;$$

$$S_{FG♂} = \frac{N_{♂}\Sigma F_{♂}G_{♂} - (\Sigma F_{♂})(\Sigma G_{♂})}{N_{♂}} = 1294.29.$$

Similar quantities are then computed for the females. From these two arrays we form (1) the differences in the means

$$\begin{aligned}
d_B &= \bar{B}_{♂} - \bar{B}_{♀} = 47.173469 - 41.520000 = 5.653469 \\
d_F &= \bar{F}_{♂} - \bar{F}_{♀} = 90.551020 - 81.800000 = 8.751020 \\
d_G &= \bar{G}_{♂} - \bar{G}_{♀} = 74.142857 - 78.210000 = -4.067143
\end{aligned}$$

and (2) the elements of the sum of the products of deviations matrix

$$\begin{aligned}
S_{BB} &= S_{B\text{♂}} + S_{B\text{♀}} = 738.06 + 450.96 = 1189.02\\
S_{FF} &= S_{F\text{♂}} + S_{F\text{♀}} = 2512.24 + 1602.00 = 4114.24\\
S_{GG} &= S_{G\text{♂}} + S_{G\text{♀}} = 2560.00 + 1880.59 = 4440.59\\
S_{BF} &= S_{BF\text{♂}} + S_{BF\text{♀}} = 792.63 + 529.40 = 1322.03\\
S_{BG} &= S_{BG\text{♂}} + S_{BG\text{♀}} = 660.57 + 430.08 = 1090.65\\
S_{FG} &= S_{FG\text{♂}} + S_{FG\text{♀}} = 1294.29 + 1143.20 = 2437.49.
\end{aligned}$$

Step 2. The sum of products of deviations matrix and the computation of the λ's. We now construct the symmetric matrix whose elements are

$$\begin{array}{cccc}
S_{BB} & S_{BF} & S_{BG} & d_B\\
 & S_{FF} & S_{FG} & d_F\\
 & & S_{GG} & d_G
\end{array}
\qquad
\begin{array}{cccc}
1189.02 & 1322.03 & 1090.65 & 5.653469\\
 & 4114.24 & 2437.65 & 8.751020\\
 & & 4440.59 & -4.067143.
\end{array}$$

To this matrix we adjoin a unit matrix, and the extended matrix so formed appears as follows:

$$\begin{array}{cccccccc}
 & & & & & & & \text{Sum}\\
1189.02 & 1322.03 & 1090.65 & 5.653469 & 1 & & & 3608.353469\\
(1322.03) & 4114.24 & 2437.65 & 8.751020 & 0 & 1 & & 7883.671020\\
(1090.65) & (2437.65) & 4440.59 & -4.067143 & 0 & 0 & 1 & 7965.822857.
\end{array}$$

The column headed "Sum" is obtained by summing across all of the elements in the row.

To obtain the estimates of the λ's we are required to reduce this extended matrix. A convenient method of reduction is the "square root method" (for a detailed presentation of this and other methods of reduction and a description of the errors in these methods the reader is referred to Dwyer, '51). To reduce the matrix by this method we proceed as follows: We may ignore the terms in parentheses in the above matrix, and compute the matrix whose elements are as indicated below:

$$\begin{array}{ccccccc}
s_{11} & s_{12} & s_{13} & d_1 & t_{11} & 0 & 0\\
 & s_{22\cdot 1} & s_{23\cdot 1} & d_2 & t_{21} & t_{22} & 0\\
 & & s_{33\cdot 12} & d_3 & t_{31} & t_{32} & t_{33}
\end{array}$$

where the s elements are obtained by operating on the S's, the d elements on d_B, etc., and the t elements from the unit matrix. The s, d, and t elements are calculated as follows:

$$s_{11} = \sqrt{S_{BB}} = \sqrt{1189.02} = 34.482169$$

$$s_{12} = \frac{S_{BF}}{s_{11}} = \frac{1322.03}{34.482169} = 38.339526$$

$$s_{13} = \frac{S_{BG}}{s_{11}} = \frac{1090.65}{34.482169} = 31.629391$$

$$d_1 = \frac{d_B}{s_{11}} = \frac{5.653469}{34.482169} = 0.163953$$

$$t_{11} = \frac{1}{s_{11}} = \frac{1}{34.482169} = 0.029000$$

$$s_{22\cdot 1} = \sqrt{S_{FF} - (s_{12})^2} = \sqrt{4114.24 - (38.339526)^2} = 51.422959$$

$$s_{23\cdot 1} = \frac{S_{FG} - (s_{12})(s_{13})}{s_{22\cdot 1}} = \frac{2437.65 - (38.339526)(31.629391)}{51.422959} = 23.821930$$

$$d_2 = \frac{d_F - (s_{12})(d_1)}{s_{22\cdot 1}} = \frac{8.751020 - (38.339526)(0.163953)}{51.422959} = 0.047939$$

$$t_{21} = \frac{0 - (s_{12})(t_{11})}{s_{22\cdot 1}} = \frac{0 - (38.339526)(0.029000)}{51.422959} = -0.021622$$

$$t_{22} = \frac{1}{s_{22\cdot 1}} = \frac{1}{51.422959} = 0.019447$$

and

$$s_{33\cdot 12} = \sqrt{S_{GG} - (s_{13})^2 - (s_{23})^2}$$

$$d_3 = \frac{d_G - (s_{13})(d_1) - (s_{23})(d_2)}{s_{33\cdot 12}}$$

$$t_{31} = \frac{0 - (s_{13})(t_{11}) - (s_{23})(t_{21})}{s_{33\cdot 12}}.$$

$$t_{32} = \frac{0 - (s_{23\cdot 1})(t_{22})}{s_{33\cdot 12}}$$

$$t_{33} = \frac{1}{s_{33\cdot 12}}.$$

It should be noted that the computations for the second and third (or subsequent) rows are analogous. In the present example, we obtain the following values:

							Check
34.482169	38.339526	31.629391	0.163953	0.029000	0	0	104.644040 104.644039
	51.422959	23.821930	0.047939	—0.021622	0.019477	0	75.290652 75.290653
		53.597456	—0.193943	—0.007504	—0.008643	0.018658	53.406023 53.406024.

The rightmost column in the above matrix affords a check of the computations. It will be noticed that each row has two entries in this column. The first entry is computed from the sum in the original extended matrix by the same method used to generate the other entries in the row, thus

$$\text{first row} = \frac{3608.353469}{34.482169} = 104.644040$$

$$\text{second row} = \frac{7883.671020 - (104.644040)(38.339526)}{51.422959} = 75.290652$$

$$\text{third row} = \frac{7965.822857 - (104.644040)(31.629391) - (75.290652)(23.821930)}{53.597456} = 53.406023.$$

The second entry is obtained by summing the elements across the row, for each row, in the reduced matrix. These entries should be equal, or nearly so, if the computations have been correctly performed.

Now to compute the estimates of the λ's and their variances we employ terms obtained from the reduced matrix. It can be shown that

$$\lambda_3 = \sum_i d_i t_{i3} = (-0.193943)(0.018658) = -0.003619$$

$$\lambda_2 = \sum_i d_i t_{i2} = (-0.193943)(-0.008643) + (0.047939)(0.019447) = 0.002609$$

$$\lambda_1 = \sum_i d_i t_{i1} = (-0.193943)(-0.007504) + (0.047939)(-0.021622) + (0.163953)(0.029000) = 0.005173.$$

Step 3. The significance of the discriminant function and the errors associated with the λ's. Once the values of the λ's associated with the linear compound are computed we must determinine whether the discriminant function is effective. Otherwise stated, we are concerned to determine whether significant discrimination is achieved. The significance of the discriminant function can be ascertained by an analysis of variance. We form the analysis of variance table

SOURCE	SUM OF SQUARES	DF	M.S.	F
Between sexes	$\sum_i N_i(\bar{X}_i - \bar{X})^2 = \frac{N_1 N_2}{N_1 + N_2}[\sum_i \lambda_i d_i]^2$	p	A	A/B
Within sexes	$\sum_{ij}(X_{ij} - \bar{X}_i)^2 = \sum_{ij} \lambda_i \lambda_j S_{ij}$	$N_1 + N_2 - p - 1$	B	
Total	$\sum_{ij}(X_{ij} - \bar{X})^2$	$N_1 + N_2 - 1$		

In the illustrative example, we find

SOURCE	SUM OF SQUARES	DF	M.S.	F
Between sexes	0.220776	3	0.073592	213.930
Within sexes	0.066798	194	0.000344	
Total	0.287574	197		

The F is significant for 3 and 194 degrees of freedom, indicating that significant discrimination is achieved. Were F not significant, the discriminant function would be ineffective in classifying sex.

A further measure of the effectiveness of the discriminant function can be gleaned from a comparison of the individual λ's with their standard errors (see Kendall, '48). At this juncture, it should be pointed out that the approach to be described is not without difficulty since the coefficients, the λ's, of the discriminant function are not unique in the sense that they are estimates of specific population parameters, only their ratios are unique.

The standard errors of the coefficients we compute from the mean square within samples and elements obtained from the reduced matrix obtained in step 2. It can be shown that

$$\sigma_{\lambda_3}{}^2 = 0.000344 \sum_{i=1}^{3}(t_{3i})^2 = 0.000344(0.018658)^2 = 0.000000119754$$

$$\sigma_{\lambda_2}{}^2 = 0.000344 \sum_{i=1}^{3}(t_{2i})^2 = 0.000344[(-0.008643)^2 + (0.019447)^2]$$
$$= 0.000000177593$$

$$\sigma_{\lambda_1}{}^2 = 0.000344 \sum_{i=1}^{3}(t_{1i})^2 = 0.000344[(-0.007504)^2 + (-0.021622)^2 + (0.029000)^2]$$
$$= 0.000000469498$$

and hence

$$\sigma_{\lambda_1} = 0.00068520$$

$$\sigma_{\lambda_2} = 0.00039471$$

$$\sigma_{\lambda_3} = 0.00034605.$$

Since each of the λ's exceeds twice its standard error, we may assert that each of the measurements contributes to the effectiveness of the discriminant function. If one or more of the λ's did not exceed twice its standard error, this would imply that the measurements associated with these λ's did not contribute significantly to the discriminant function. These measurements could then be discarded, and a new discriminant function computed. In practice, this would amount to recomputing the entries in the rows following the row corresponding to the first discarded measurement. If the last row (or rows) is omitted, no further computation is necessary. A corollary of this would lead one to place in the last row that measurement which on an *a priori* basis would seem to contribute the least to the discriminant function.

Step 4. The discriminating value: To assign individuals to one of the two populations sampled we need a standard of judgment. This standard we shall term the discriminating value, and shall assign to one population values which exceed this standard and to the other population values less than this standard. We compute the discriminating value as follows: We determine, first, the means of the linear function associated with the two populations, thus

$$\begin{aligned}\bar{X}_{♂} &= \lambda_1\bar{B}_{♂} + \lambda_2\bar{F}_{♂} + \lambda_3\bar{G}_{♂}\\ &= (0.005173)(47.173469) + (0.002609)(90.551020)\\ &\quad + (-0.003619)(74.142857)\\ &= 0.211953\end{aligned}$$

$$\bar{X}_{♀} = \lambda_1\bar{B}_{♀} + \lambda_2\bar{F}_{♀} + \lambda_3\bar{G}_{♀} = 0.145157.$$

To obtain the discriminant value, $\bar{X}$, we merely solve

$$\bar{X} = \frac{\bar{X}_{♂} + \bar{X}_{♀}}{2} = 0.178555.$$

Accordingly, we shall assign to the male population those individuals where the discriminant function exceeds 0.178555, and to the female population those individuals where the discriminant function is less than 0.178555. A discussion of the rationale underlying the choice of the discriminating value will be found in Rao ('52, p. 296).

In scoring individuals, it is often convenient to convert the λ's to values more easily remembered. The actual values are relatively unimportant since discrimination rests on the proportional relationships. We may, then, divide λ_1, λ_2, and λ_3 by a constant factor, say λ_2, which would make $\lambda'_1 = \lambda_1/\lambda_2$, $\lambda'_2 = 1$, and $\lambda'_3 = \lambda_3/\lambda_2$, and in the present example, $\lambda'_1 = 1.9828$, $\lambda'_2 = 1.0000$, and $\lambda'_3 = -1.3871$. This device, of course, leads to a change of scale in the discriminant function with the new discriminating value being 68.42.

Step 5. The classificatory error: We have indicated that the purpose of a discriminant function is to facilitate assigning to one of two or more populations an observation known to have been drawn from one, unspecified member of this group of populations. If the populations involved are uniquely different, obviously no discriminant function is necessary. More frequently, however, the populations are not unique and hence there arises the possibility of misclassification of an observation. One of the advantages of the discriminant function is the opportunity which it affords to appraise the classification error in an objective fashion, an advantage not enjoyed by subjective or unquantified experimental standards.

To compute the classification error associated with a discriminant function we proceed as follows, again using the illustrative material: We have indicated in the previous section that we shall assign an observation to the male population if the value of the discriminant associated with the observation exceeds 0.178555, to the female population if the value of the discriminant function is less than 0.178555, and in the unlikely event that the discriminant value observed was precisely equal to 0.178555 we would assign the observation to the male or female group by tossing a coin (if λ'_1, λ'_2, and λ'_3 are used then 0.178555 must be replaced by 68.42). Now we should expect, by chance, to obtain some male values which were smaller than 0.178555 and would, therefore, be erroneously assigned to the female population, and conversely, we should expect to obtain some female values which were larger than 0.178555 and which would be erroneously assigned to the male population. Our task is to determine how frequently these two events would occur. As a consequence of the assumption that each sample is drawn from a p-variate normal population, the observed discriminant values, for a given population, will be normally distributed around the mean value for that population, hence Negro male values will be normally distributed about the mean 0.211953, and female values around 0.145157. The error frequency associated with females, then, will correspond to the area to the right of 0.178555 of a normally distributed variable with mean 0.145157, and variance equal to 0.00034432 (mean square within sexes).

Now the normal deviate with zero mean and unit variance is merely

$$\frac{0.178555-0.145157}{0.00034432}=\frac{0.033398}{0.018556}=1.800.$$

From a table of the normal deviate, we note that 3.6% of the area lies to the right of this value. We should, then, misclassify females with a frequency of roughly four in one hundred. The frequency with which males would be misclassified would be the same since the discriminating value is so chosen as to equalize the classificatory errors.

Suppose, now, that an unknown specimen was drawn from the 198 individuals available to us, and we ask how frequently would we misclassify this "unknown" individual. This frequency would merely be the sum of the products of (1) the probability of drawing a male and the probability of misclassifying him, and (2) the probability of drawing a female and the probability of misclassifying her. Since the frequency of males and females is approximately 1 : 1 in this group, this sum is merely 3.6%.

DISCRIMINANT ANALYSIS RESULTS

In carrying out discriminant analysis it is necessary to get sums of the cross products for each individual pair of the measures used. Inasmuch as two of our series, one male and one female, could not be measured for the epicondylar width of the humerus, the calculations for the statistics for each measurement and for the discriminant function are based upon a reduced sample (98 male and 100 female). The figures 1-7 include the whole series. The measurements of these two individuals were not in the 'problem' range for the ischium-pubis index and their removal from the sample has little effect. (Sample used is shown in Table 1).

Table 2 gives the correlation coefficients between all of the 7 measurements used. (Sternum width was not used as this would have reduced the female sample even further and because it is not a very good discriminator. as can be seen in figure 2).

TABLE 2

Correlation coefficients between all pairs of measurements used in the discriminant analysis

MEASUREMENT	A	B	F	G	C	D	E
A	1.0000						
B	.4627	1.0000					
F	.6477	.5983	1.0000				
G	.6011	.4753	.5708	1.0000			
C	.8108	.4280	.5902	.5086	1.0000		
D	.4179	.5356	.5083	.4370	.4212	1.0000	
E	.5629	.2625	.4295	.4475	.5257	.2709	1.0000

where A = femur length
B = femur head diameter
F = ischium length
G = pubis length
C = humerus length
D = epicondylar width of humerus
E = clavicle length

Table 3 gives the coefficients of variation (proportion of variation in one variable explained by variation in another). In table 4 some results (3, 4, 6 and 7 measure combinations) of the discriminant analysis are given.

In figure 8 the data from this series are used to test how one set of values developed in the discriminant analysis apply to this particular series. The discriminant function for 4 measurements is calculated for each individual and the values plotted on a scale. Figure 8 shows that the totals for three males are less than 665, the limit value, and one female more. In other words, 4 individuals, or 2% of the series, are not accurately sexed. The probability of wrong classification of

3.1%, as calculated in the discriminant analysis, was in fact slightly bettered.

In the 6 measurement analysis, only two skeletons,[2] one female and one male, are not properly sexed when the values are applied to this series. The same two individuals are again not sexed in the 7 measurement series.

TABLE 3

Coefficients of variation (proportion of variation in one variable explained by variation in another) between all pairs of measurements used in the discriminant analysis

MEASUREMENT	A	B	F	G	C	D	E
A	1.0000						
B	.2141	1.0000					
F	.4195	.3580	1.0000				
G	.3613	.2259	.3258	1.0000			
C	.6574	.1832	.3483	.2587	1.0000		
D	.1746	.2869	.2584	.1910	.1774	1.0000	
E	.3169	.0689	.1845	.2002	.2764	.0734	1.0000

where A = femur length
B = femur head diameter
F = ischium length
G = pubis length
C = humerus length
D = epicondylar width of humerus
E = clavicle length

In practice the values given in table 4 are quite simple to use. Three, 4, 6, or 7 measurements are taken, the appropriate multipliers are used as shown in the table and the totals of these products are obtained. If the total is under the limit value, the skeleton is female; if over, it is male.

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[2] The males with a femur head diameter of only 40 mm would have been correctly sexed if it had instead been 42 mm. The female, with a femur head of 47 mm would have been correctly sorted if it had been 45 mm. The ischium-pubis index for the male is 85.2 and the female 89.0, both in the "overlap area." It is in the unusual diameters of the femur head that these two skeletons are especially deviant.

TABLE 4

The results of the discriminant analysis for combinations of 3, 4, 6 and 7 measurements as given in multipliers to be used, the limit values, probabilities of misclassification and expected ranges

	7 × 7	6 × 6	4 × 4	3 × 3
A. Femur length	.07	1.00	1.00	
B. Femur head diameter	58.14	31.40	16.53	1.98
F. Ischium lenth	16.25	11.12	6.10	1.00
G. Pubis length	—63.64	—34.47	—13.80	—1.39
C. Humerus length	2.68	2.45		
D. Epicondylar width of humerus	27.68	16.24		
E. Clavicle length	16.09			

Discriminating values

	VALUE SEPARATING THE SEXES (♀ ARE LESS THAN THE VALUE)	PROBABILITY OF ERROR IN CLASSIFICATION PER CENT	RANGE WITHIN WHICH 99% WILL FALL
7 × 7	4099	1.5	2664-5533
6 × 6	1953	2.5	1205-2701
4 × 4	665	3.1	367-963
3 × 3	68	3.6	50-86

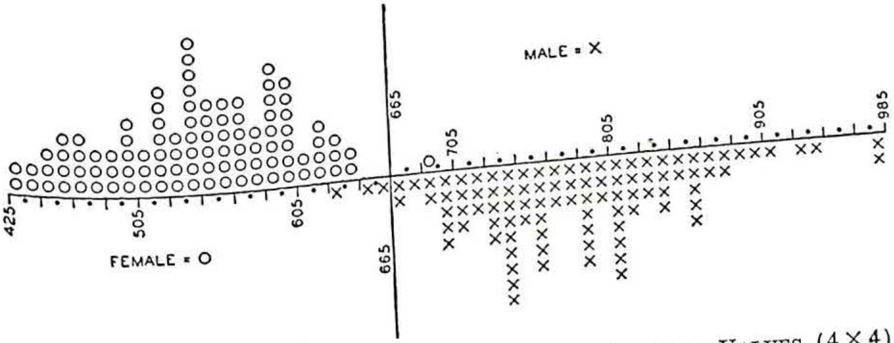

FIG. 8. THE RESULTS OF A TRIAL OF DISCRIMINANT ANALYSIS VALUES (4 × 4) APPLIED TO 198 AMERICAN NEGRO BONES OF KNOWN SEX.

For example, an actual case which cannot be sexed by ischium-pubis index or femur head size has the following measurements:

1.	femur length	429
2.	femur head diameter	44
3.	ischium length	84
4.	pubis length	73

The multipliers from table 4 give:

$$\begin{aligned} +\ 1.00 \times 429 &= 429.00 \\ +16.53 \times 44 &= 727.32 \\ +\ 6.10 \times 84 &= 512.40 \\ -13.80 \times 73 &= -1007.40 \\ \text{Total} &= \overline{\ \ 661.32} \end{aligned}$$

As the limiting value is 665 and all under it are female, this skeleton is classified correctly as female.

RIGHT-LEFT ASYMMETRY BY SEX

In table 5 the results are given by right-left comparisons for the femur, humerus and clavicle by sex.

TABLE 5

Dominance in length in right-left comparisons by sex in percentage for three bones from each of 200 American Negroes

MEASUREMENT	MALE			FEMALE		
	Right	Left	Equal	Right	Left	Equal
Femur	37.4	44.4	18.2	35.2	50.5	14.3
Humerus	44.0	42.0	14.0	71.4	14.3	14.3
Clavicle	23.0	65.0	12.0	38.1	52.4	9.5

There is a striking dominance for the right side in the humerus for females and for left dominance in male clavicles. While the pattern for both sexes is apparently right-armed and left-legged, the simple functional explanation that this implies does not hold for the clavicle. Trotter and Gleser ('52) find this same dominance pattern with the exception that in their Negro males series the left humerus was slightly longer than the right, but the right arm dominance was borne out for radius and ulna. In our series the right is only slightly more frequent than the left.

While of no obvious value for sexing skeletons, these right-left differences are not the same for each sex and should be explained by something other than mere functional handedness dominance. The absolute size of the mean differences between sides is small with the largest being 4.5 mm in the left male clavicle.

DISCUSSION

The extent of sexual variability for several measurements is given in figures 1-6. Methods of sorting individual skeletons based on this variability pattern have also been presented. These methods, while highly efficient for this series of adult American Negroes, may have different value for sexing other series, or individuals from other populations. What degree of general applicability do these methods have? The answer to this depends first, upon the degree that gross size varies *between* populations for each sex, and second, on the degree that the sexual dimorphism in the skeleton is the same *within* these populations. The answer to the first question is obvious. Variation in size is marked between races, and consequently the absolute size of the limiting values separating the sexes must be revised for each race according to their relative place on a scale of racial variation in mean size for each measurement. For instance, while 44 mm may be the point in the scale of size of the head of the femur which best separates Negro males and females, it would undoubtedly be a smaller value for some other groups and larger for still others.

The second question dealing with the degree of regularity in the expression of relative sex differences within the varieties of mankind is not so easily answered. The fundamental pattern for sexual dimorphism is basically a species characteristic but we are concerned here with the degree that a racial variation exists within the species. We have no precise answer to this question. Schultz ('37) states, ". . . the various human races differ but very little in the degree with which the males surpass the females in the length of the long bones." He shows that the relative length of the female to male humerus or femur is between 91% and 93% for White, Negro, Eskimo, and American Indian series with an average of 91.84%. In Portuguese (Pons, '55) it is 89.5% and in our series it is 92.0. Hrdlička ('47) indicates little or no sex differences in the ratio of femur length to stature for either the White or Negro races. Pearson (1899) in accumulating his basic data used for deriving curves for estimating stature from long bones was of the same opinion. In fact, the early workers dealing with the problem of estimating stature felt that possibly a single formula was equally efficient despite differences in race as well as sex. Recent studies (Dupertuis and Hadden, '51; Trotter and Gleser, '52) however, have shown that this is not the case and that each race probably has a slightly different formula describing the relationships. Trotter and Gleser go even further and find that there are differences for both race and sex. They state (p. 511), "It is evident . . . that it is necessary for the sake of obtaining the most accurate estimates of stature to have different equations for each of the two sexes and for each of the two (White and Negro) races." From their data we may conclude that the pattern of dimorphism, while not identical for these races, is only slightly different. In conclusion, there is a predominant similarity in the degree of sexual dimorphism for man with a minor but unknown amount of difference at the racial level.

Schultz ('30, '37, '49) has shown that in comparing the relative proportions by sex in the long bones of man and the apes there are appreciable differences among these primate forms. Also the ischium-pubis relations are quite different with a much greater overlap between the sexes in the ape index than in man. Washburn ('42) has shown that for three species of monkeys the index is different from man with no overlap occurring between the sexes. Schultz ('37) has also shown that the extent to which the sexes differ in size fluctuates widely in primates. He concludes that man stands in regard to the size of sex differences in between the macaque and chimpanzee on one side and the orang-utan and gorilla on the other. From these data describing differences in primate skeletons of known sex we may conclude that the expression of sexual dimorphism differs among primate forms. There is no basic primate pattern holding for all varieties, nor is there apparently a monkey pattern or an ape pattern, yet man seems to have a highly homogeneous pattern within the species.

In light of the previous discussion, we may draw the following conclusions. First, we can effectively operate at present on the assumption that the expression of sexual dimorphism is relatively similar in pattern for all varieties of man. This means that the shape of the bimodal curves describing sexually varying characters within populations will be approximately the same. Second, the location of these curves on a scale of absolute size will vary for different races. The limit values efficient for separating the sexes will consequently vary.

Consideration of these conclusions about the nature of the sexing problem suggests a practical application of our discriminant analysis beyond the American Negro population. An assumption of normal distribution is basic to the discriminant analysis. As our problem is to redefine the limit value for other populations, the following method is suggested, based upon the expectation that normal curves will describe the variability in any population for these measurements. If mean values for each combination of measurements as used in this study are known by sex for any other group, the multipliers can be used and an average value for each sex determined. The discriminating limit for any population will be one half the difference between these average values for each sex. Limit values so determined could be applied to skeletons of unknown sex with a high level of confidence.

Continuing to point out practical approaches to the problem of sexing skeletons, we might mention the results obtained when an analysis of discrimination for a redefined ischium-pubis index measurement is done. The ischium-pubis index as previously used has ill-defined landmarks and thus suffers in accuracy. The following is offered as an improvement.

If the pubic measurement were to be taken from the nearest acetabulum border to the superior point of the pubic symphysis and the ischium length to the far border of the acetabulum, the femur head size also would be included in the single index. Femur head diameter should be included because it is probably the best single measurement for sexing and would be included in this index because it is highly correlated with acetabulum size. To test roughly this idea, an index was made by taking pubis length minus half the femur head diameter dividing by ischium length plus half of femur head diameter. Using this method, a limit value of .500 correctly sexed all but 7 individuals in the series which is success at the 96.5% level. While this method is not precisely what was recommended, the limit value for this method will probably be close to .5 which would make it quite easy to use. A series of known sex pelves should be studied to determine what the real limit should be and how efficient it is.

Additional support of the idea that femur head should be used with the pubis in making a simple sexing index is the fact that in this series a pubis-femur head index is more efficient than the ischium-pubis index. Using a value of 89.0 for the limiting value in ischium-pubis index, 13 individuals are not properly sexed, whereas using a limit value of 1.72 for pubis-femur head, only 11 are not properly sexed.

There are many "hallmarks" of sex that are proposed by various authors,[3] yet it seems that the efficiency achieved in sexing the skeleton by measurement or morphological form has about reached the upper limit. We notice in examining the nature of variability in the features recommended in the literature for use in measurement or observation that there are certain deviant individuals who are completely out of their expected range.

The variability for the "hallmarks" of sex in the skeleton is distributed along pathways separating only after an undifferentiated pre-puberty. Comparing the sexes, the males differ from pre-puberty most in changes in gross size of long bones, as can be seen from any growth curve. The females differ less in longitudinal growth but show special effects of endocrine mediated changes. Washburn ('48) in discussing this has shown that while the range of ischium-pubis index is the same for each sex before puberty, with puberty the female alone has appreciable growth in pubis length. Analysis of the patterns of variability by sex seems to indicate that the 'hard to sex' skeletons—the deviant individuals—are the males who did not achieve their expected size change and the females who exceeded expectation. The failure of individuals to conform to the expected endocrine patterns seems much less frequent. Without exception the standard error of the mean for male variability is greater than for females. The number of males to females in the "overlap" range for ischium-pubis index is 25:15. For Washburn's series ('48, '49) the ratio for American Negroes is 13:4, and for Bantu it is 19:3. From this it seems that the problem cases for sexing are the males who have interference with their normal longitudinal growth, and females who greatly exceed the average for their sex. Possibly a series of healthy individuals would give skeletons free of any problem cases. As most human skeletons of known sex come from dissecting room material we do not know to what extent the peculiarities of this sample source create difficulties in sexing.

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[3] An example is given in a recent study of Sauter and Privat ('55). They summarize many previous methods as well as propose a new index. A more thorough summary of sexing procedures and a study of sex differences in the innominate bone suggesting new methods is given by Genoves ('55).

One clear conclusion to be drawn from this study is that sex in the skeleton can be determined with great accuracy. In an unknown series of American Negroes, using the 7 × 7 discriminant analysis values, over 98% accuracy is assured. The levels are lower for other methods but the results are still better than those obtained if sexing is done by using apparent total morphological configuration.

In view of the controversy over this point (Stewart '54), some remarks seem in order. In the first place it should be mentioned that the probability statements that are a property of a certain method apply only to series in which discrimination is done by that method. If a single specimen is to be sexed, the relative position of that individual on the total scale of variability for sex is what dictates the probability. By eye or by measure it may be readily known that there is little chance of incorrect sexing. For instance, in figure 8 the two males with values over 975 are *certainly* male. The point is not that one can be sure, but rather it is that the inexperienced person can be as sure as the expert. In the alternate cases where the signs of sex are confusing and the values are close to the limit value, the beginner or the expert can be equally certain of the doubtful nature of the case. It is most important that the beginner, and possibly the expert as well, should know when he is in trouble. The measurement method can tell him.

Stewart ('54) writes that attempts to sex by measurement are not better than the old methods which gave greatest weight to total morphological configuration. He interprets Washburn and Hanna ('53) to recommend that "measuring the pelvis should replace the traditional method in which the whole skeleton. or whatever part is available is inspected." (p. 389.) He concludes that only in special cases should it ever be necessary to measure and that this method be applied only when there is a certain basis for the need to use measurement. Stewart goes on to say. "It is a waste of time and effort to measure such specimens (the better differentiated ones) simply to verify what the eye so quickly discerned." It is undoubtedly true that measurement is more laborious but the crux of the matter is not this. The error lies in the fact that sexing by eye, although it uses one 'tool,' is not one method. Stewart's remarks are quite in order if he is commenting on the problems of sexing an isolated single specimen. On the other hand, for determining sex in a series it is obviously of value to use a single and explicit method. Different criteria should not be used for each specimen if it can be avoided. Otherwise there is no possibility of accurately estimating error and an element of uncertainty of an indeterminate amount will color and dilute the security of any related conclusions.

The appeal of the measurement method is primarily derived from the degree that verifiable scientific methods are introduced to replace less satisfactory ones. There are cases where fragmentary evidence and unusual circumstances require the services of an expert who must almost intuitively arrive at conclusions, but this does not mean that such an approach is satisfactory when it is unnecessary. The introduction of precise measurement methods does not rule against the need for the expert but rather adds variety to his methods and demonstrable certainty to his conclusions.

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THE PHYSIOLOGICAL EFFECTS OF SLEEPING ON HARD OR SOFT BEDS[1]

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INTRODUCTION

CIVILIZED people employ a range of sleeping surfaces which includes those which are extremely soft and those which are very hard, often being but a wooden floor covered by a thin mat. It thus appears that man is able to sleep on any surface to which he is accustomed. The question of the advantage of one type of supporting surface over another appears, however, to be unsettled. With this problem in mind the present study has been conducted to determine whether there is any appreciable variation in certain physiological reactions recorded during sleep which can be related to the properties of the surface on which the sleeping subject is supported. Since it is not feasible to attempt to evaluate the quality of sleep under different conditions, sleep has been measured quantitatively in terms of its depth and duration. Quantification has been made on the basis of EEG recordings confirmed by stimulus-response studies. This objective evaluation has been compared to the nightly subjective estimate of the sleepers. In addition several other physiological variables (body movement, heart rate and skin temperature) have been recorded to supply still more information concerning the course of sleep during the night.

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[1] This work was conducted in the Sleep Laboratory of the U. S. Testing Company. Support was received from the Simmons Company.

METHODS

The results discussed here were obtained from two adult male subjects who slept under observation for 5 nights a week during a period of 6 weeks and two others who slept under observation 5 nights a week for three weeks. This comprised a total of 90 sleep nights. The sleepers rotated through three different, constant temperature, sound-conditioned sleep rooms which differed only in the nature of the sleeping surface provided. One room contained a standard modern innerspring mattress, one a feather bed, and one a sheet of $1\frac{1}{2}$ cm plywood covered by a thin carpet. The hardness of the various supporting surfaces was evaluated by means of a deflection test. Known weights ranging up to 150 kg were placed on a board measuring 45 by 90 cm and located in the approximate center of the supporting surface. The depression of the board due to the compliance of the supporting surface was then registered over the range of weights used. Figure 1 shows that a marked difference in hardness was provided by the three supporting surfaces employed. In subsequent sections the board is referred to as the "hard" surface, the standard mattress as "medium," and the feather mattress as "soft."

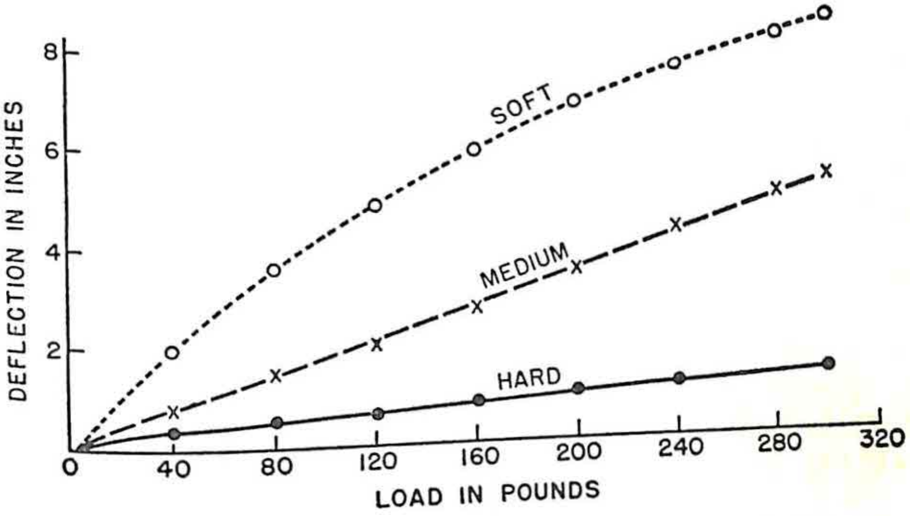

FIG. 1. LOAD-DEFLECTION CURVES FOR THE THREE SUPPORTING SURFACES. O----O SOFT; ×---× MEDIUM; ●——● HARD.

The EEG was recorded from frontal, temporal and occipital leads with small silver electrodes sealed to the scalp by several layers of collodion. A pre-sleep record was obtained and then immediately following lights-out a continuous record was taken for 20 minutes. In most instances this interval was sufficient to cover the initial going-to-sleep period of each subject. Subsequently the EEG was recorded for two minutes out of each 5 during the remainder of the 7-hour sleep period. The EEG records were evaluated by means of the usual criteria (Blake *et al.*, '39; Davis *et al.*, '39 and Gibbs and Gibbs, '50) and estimated depth of sleep was graded from 0 = awake to 4 = deepest sleep. (Hoffman *et al.*, '56 and Brooks *et al.*, '56).

The accuracy of the estimation of sleep-depth for each subject was checked by means of stimulus-response studies employing sound stimuli of known relative intensities. Tone pulses at 1500 cps and of 500 msec duration were delivered to each subject at widely spaced intervals on different nights. During these tests the EEG was monitored continuously and at each estimated depth of sleep, sound stimuli of increasing intensity were applied. The response to those stimuli was evaluated both in terms of the appearance of the "K complex" and also the stimulus intensity required to produce frank arousal of the subject.

Body movement was recorded by means of tambours attached from below to the center of the supporting surface. An attempt to equalize the recorders was made by adjusting the recorders' sensitivity for each bed so that standard movements gave deflections of similar magnitude on all three surfaces. The heart rate was determined from EEG records obtained simultaneously with the EEG. The electrocardiogram leads were attached to the anterior and posterior surfaces of the chest to avoid interference with limb movement. Skin temperature was recorded by thermocouples sealed to the plantar surface of the great toe and to the inner surface of the axilla. Each thermocouple was covered by cotton, silver foil, and several layers of tape. All electrode leads consisted of thin, flexible wires plaited into a soft cable which emerged from the pajama collar. This cable did not interfere with ordinary body movements during the night.

The subjective estimate of sleep was recorded in the following manner. Each subject was required to evaluate the previous night's sleep after wakening, by marking an appropriate point on a vertical scale ranging from 0 to 100. The range of variation in score for the 4 subjects differed widely.

All sleepers were engaged in their usual occupations during each day of the study. They reported to the sleeping rooms at 9 P. M. each night and filled in questionnaires on the activities of the day, food intake, etc. The first three nights for each subject were considered as a breaking-in period and results from these nights were not used in subsequent evaluations.

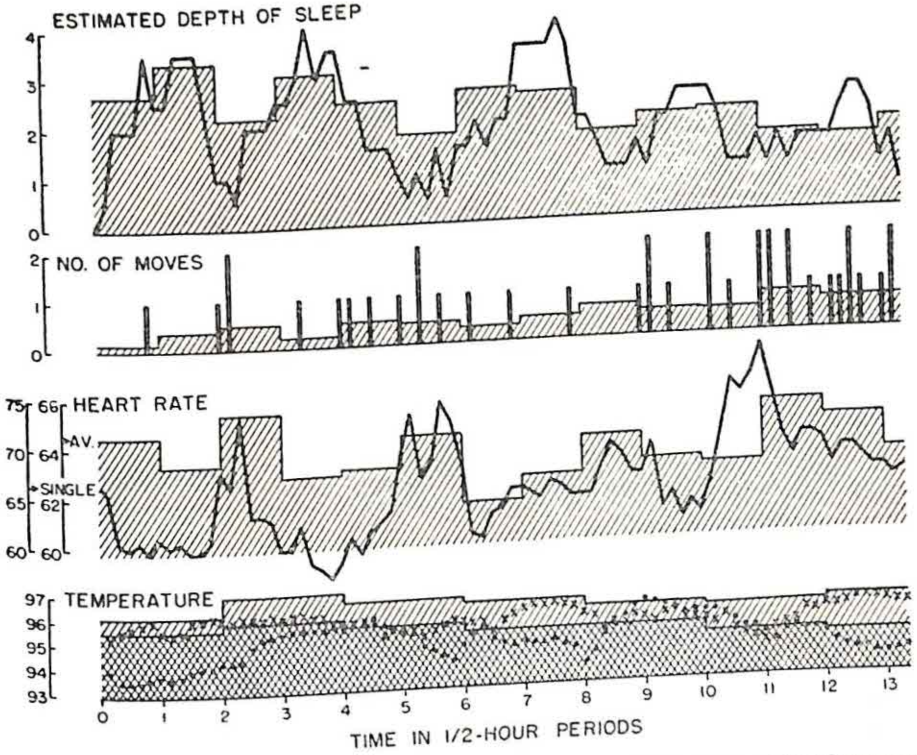

Fig. 2. Comparison of Single Night and Average Values for One Subject for all Surfaces. Single Night Plotted as Two-Minute Averages with Heavy Line, Average Values Plotted as Half-Hour Averages by Diagonally Lined Area. Toe Temperature Shown with (. . .) Half-Hour Averages (Double Diagonals), Axillary Temperature with (×××), Half-Hour Averages (Diagonal Lines).

RESULTS

Figure 2 shows a sample single night record for one subject of the estimated depth of sleep, heart rate, frequency and duration of movement, and the toe and axillary temperature. Certain of these variables warrant some mention prior to evaluation of the effects upon them of the supporting surfaces. Most important of these is the change in EEG pattern recorded at different periods of the night and its relation to the depth of unconsciousness.

Stimulus Testing of Depth of Sleep: When the EEG tracing showed predominant alpha rhythm (stage 0) or a low voltage pattern (null phase, stage 1) sound stimuli of moderate intensity did not elicit a typical and complete K complex. Somewhat stronger stimuli, however, gave rise to a wakening reaction characterized by a change in the EEG, an increase in muscle action potentials, frequent overt body movement, and often a change in heart rate. At somewhat deeper levels of sleep, identified in the EEG by a predominance of waves at 4-7 cps (stage 2) or the appearance of spindles at 14-16 cps (stage 3), low intensity sound stimuli were invariably followed by complete K complexes. At these levels stronger stimuli were required to produce arousal. In deepest sleep, characterized by delta waves and slow spindle activity (stage 4), the K complex was not recorded after moderate to strong stimuli and very intense stimulation was necessary to produce an awakening reaction. At this time also, the duration of the arousal reaction was often brief when compared to that elicited during lighter stages of sleep. In general, although there was some slight individual variation the same relationship between EEG pattern and response to stimulation was found for all subjects.

Electroencephalographic Evaluation: Direct observation of the subject and the effects of sound stimuli were both relied upon until it was thought that the depth of sleep for any subject could be estimated satisfactory from his EEG tracings alone. After this, each two-minute sample of the EEG was evaluated and assigned the appropriate numerical value (0-4). From these values a curve was constructed which represented the change in depth of sleep throughout the night (see figure 2). As has been reported previously (Hoffman *et al.*, '56; Brooks *et al.*, '56 and Kleitman, '39), there are a number of cyclic fluctuations in such a curve. The usual pattern shows a fairly rapid transition to deepest sleep (stage 4) within the first 60-80 minutes, and then a partial arousal. Subsequently, sleep again deepens but rarely reaches the depth attained initially. During the night the average levels and also the peaks of the curves tend to move from deeper to lighter sleep.

It was of some interest to note that for each subject, although there was considerable variation in the configuration of the curve on different nights, the cyclic nature of sleep depth was sufficiently consistent to appear quite prominent in the average curve for any one sleep surface (figure 3) and even for all nights combined (figure 2). The consistency of pattern was most prominent during the initial period of going to sleep; this can be seen in figure 4A, which shows the frequency with which each depth of sleep occurred in each two-minute sample during the first 80 minutes of the night. Similarly, when the average value for each half hour of the night is plotted in the same manner (figure 4B) the relative regularity of the fluctuations in sleep depth again becomes evident.

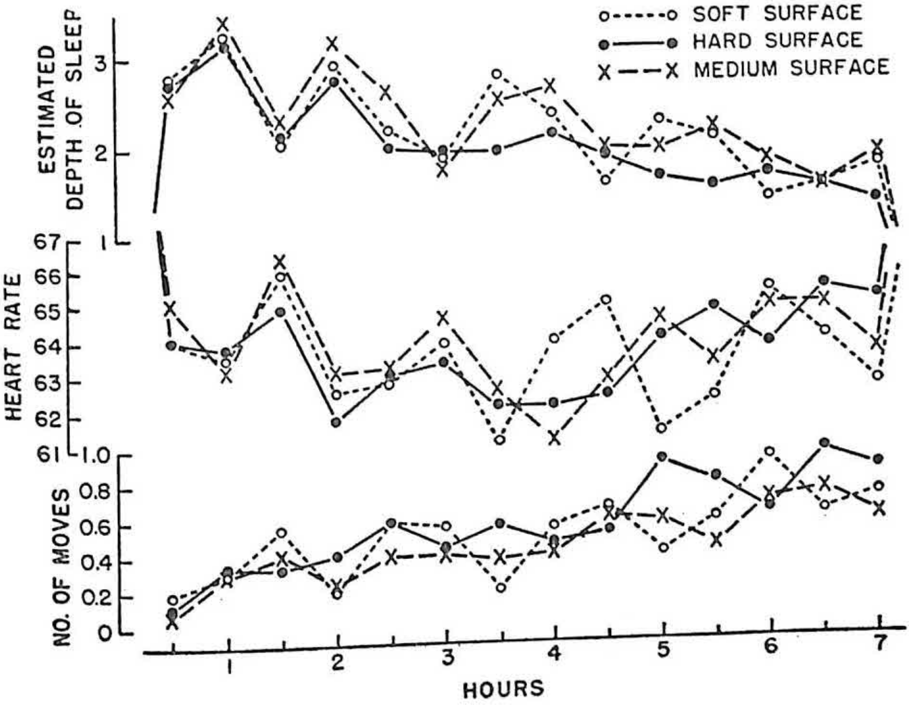

FIG. 3. AVERAGE VALUES PER HALF-HOUR FOR ESTIMATED DEPTH OF SLEEP, FREQUENCY OF MOVES, AND HEART RATE FOR SUBJECT "W" ON THE SOFT (○), MEDIUM (×), AND HARD (●) SURFACES. EACH CURVE REPRESENTS 10 NIGHTS AND EACH POINT THE AVERAGE OF 60 5-MINUTE PERIOD VALUES. HEART RATE EXPRESSED AS BEATS PER MINUTE, MOVES AS NUMBER PER 5-MINUTE PERIOD.

Heart Rate: The relationship between variations in heart rate and fluctuations in the depth of sleep are shown in figure 2. The reciprocal nature of this relationship has been demonstrated previously (Brooks *et al.*, '56) and it has also been shown that in spite of the good moment-

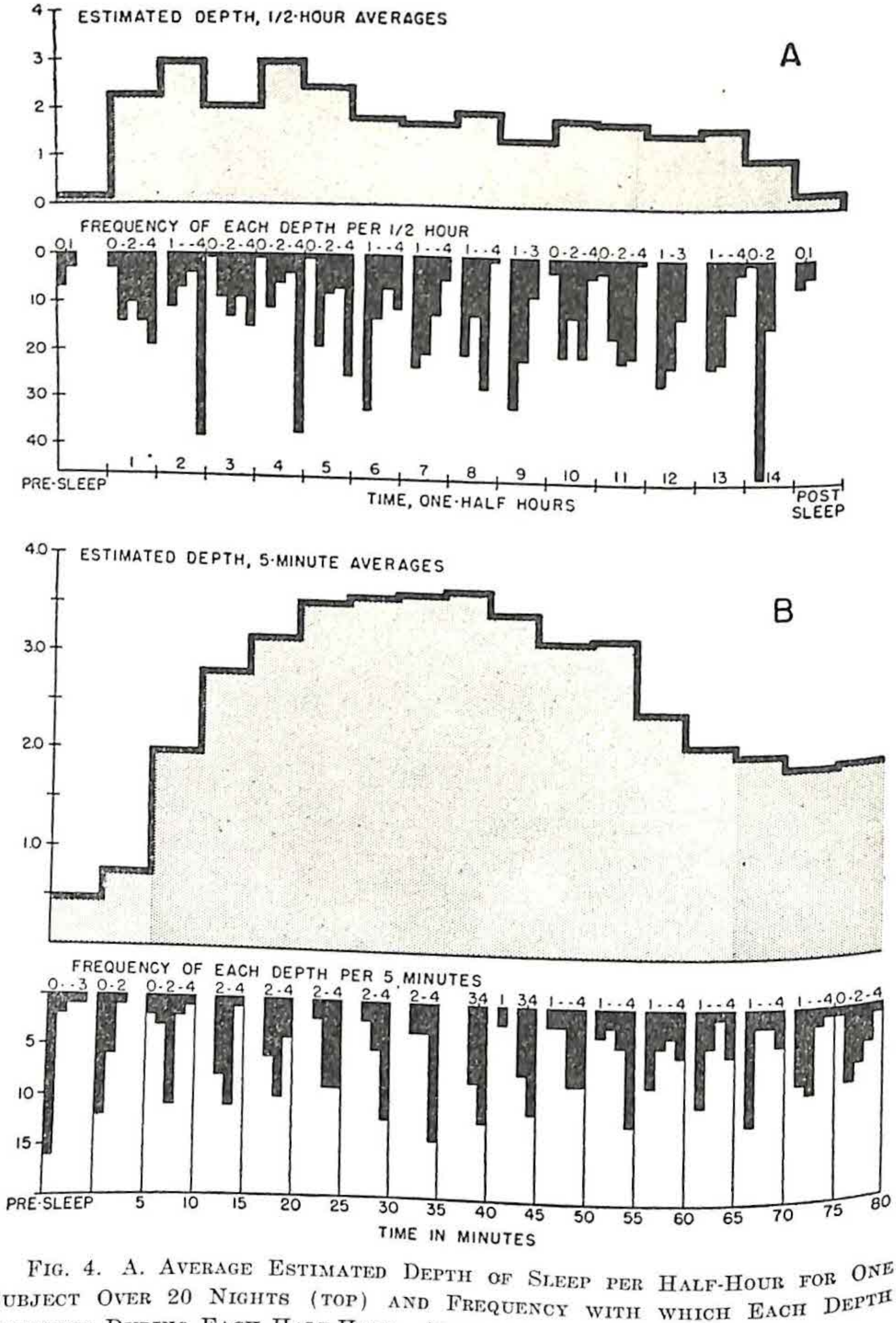

FIG. 4. A. AVERAGE ESTIMATED DEPTH OF SLEEP PER HALF-HOUR FOR ONE SUBJECT OVER 20 NIGHTS (TOP) AND FREQUENCY WITH WHICH EACH DEPTH OCCURRED DURING EACH HALF-HOUR. (BOTTOM)

B. AVERAGE ESTIMATED DEPTH OF SLEEP PER 5-MINUTE PERIOD DURING FIRST 80 MINUTES OF GRAPH IN A., AND FREQUENCY WITH WHICH EACH DEPTH OCCURRED DURING THE 5-MINUTE PERIOD.

to-moment correlation between estimated depth of sleep and heart rate, the *average* nightly heart rate is only poorly correlated with the average nightly depth of sleep (Brooks *et al.*, '56). Similar results have been obtained in the present study. Of some interest, however, is the relative magnitude of the change in heart rate for a certain change in the depth of sleep (figure 5A). Based on the average values for all subjects when the depth of sleep increased or decreased by two or three levels the heart rate slowed or accelerated by only 4 to 6 beats per minute. Since the average heart rate for all subjects was 62.5, this change amounts to less than 10%. Furthermore, the shape of the curves in figure 5B shows that the heart rate would be a less sensitive indicator of large alterations in sleep depth than of smaller changes in depth. Finally, the magnitude of the alteration in heart rate is not constant throughout the night; as seen in figure 5B, the slope of the line for the first two hours of sleep is significantly less ($p < .01$) than for the last two hours of the night.

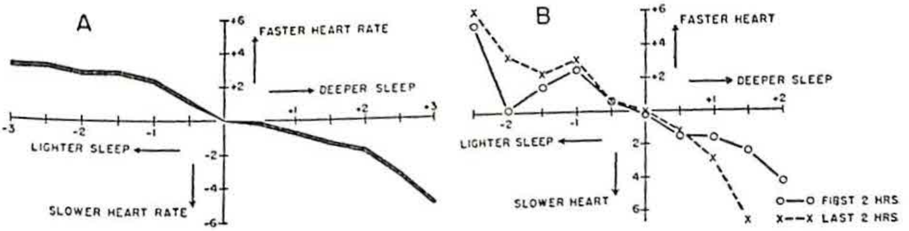

FIG. 5. A. AVERAGE CHANGE IN HEART RATE FOR A CHANGE OF GIVEN MAGNITUDE IN ESTIMATED DEPTH OF SLEEP BASED ON ALL VALUES FOR THREE SUBJECTS. ORDINATES—HEART RATE, BEATS/MINUTE; ABSCISSAE, CHANGE IN DEPTH OF SLEEP, STAGES 0-4.

B. AVERAGE VALUES FOR ONE SUBJECT, SHOWING COMPARISON BETWEEN FIRST TWO (O–O) AND LAST TWO (X–X) HOURS OF THE NIGHT.

Body Movement and Skin Temperature: Body movement appears to be associated with a decrease in the depth of sleep (figure 2). However, as has been shown in previous studies (Hoffman *et al.*, '56; Brooks *et al.*, '56 and Kleitman, '39), there is no consistent significant correlation between the number of recorded body movements on a given night and the depth of sleep on that night. The only other physiological variable consistently related in a significant fashion to frequency of body movements is the duration of each movement. Two other points concerning body movement became apparent in this study; during the first hour of sleep, body movement is less likely to be associated with an appreciable decrease in depth of sleep than later during the night; second, there is a consistent increase in the frequency of movement of all subjects as the night progresses.

The results obtained from records of toe and axillary temperatures were not rewarding. Under the conditions imposed, there was no consistent progressive change in either temperature during the course of the night (see figure 2), nor was there any significant nightly average relationship between toe and axillary temperatures or between either temperature and any of the other variables studied.

Comparison of the Supporting Surfaces: Some impression concerning the effect of the different supporting surfaces on depth of sleep estimated from the EEG may be obtained from inspection of the average curves in figure 3. In order to obtain a basis for quantitative comparison the average depth of sleep per test period for each surface was determined. These values for each of the 4 subjects are shown in table 1. It is apparent that the magnitude of the difference in average depth of sleep on each of the three test surfaces differs quite markedly between the 4 subjects: for two of them (W and He), in terms of the area under the depth of sleep curve for the entire night, this difference is appreciable; for one (P), however, the values are practically identical. These differences for each subject on each surface are summarized in table 1. It can be seen that there is a significant difference for subjects W and He between depth of sleep on the medium and hard surfaces, and only for subject W in the case of the other two comparisons.

When the results obtained for all 4 subjects are averaged (table 1) it appears that there is a group preference for both the medium and soft over the hard surface. Similar results are obtained when the depth of sleep during either the first or second half of the night is employed in place of the average for the entire night. On the other hand, if the comparison is restricted to the first hour of sleep there is no appreciable difference between any of the test surfaces with respect to either the results for each individual subject or the average results of the entire group (figure 6).

It is interesting to compare the results obtained from estimation of the depth of sleep from the EEG with the evaluation of the goodness of their night's sleep on the different surfaces by each subject (table 2). It should be noted in observing the results that the 4 subjects rated

TABLE 1

Estimated depth of sleep

SUBJECT	AVERAGE VALUE PER SURFACE*		DIFFERENCE BETWEEN SURFACES				
			Difference*	t	$p <$	Significant	Preference
Ho	S	1.94	S–H = .05	.519	.7	No	—
	H	1.89	H–M = —.11	1.170	.3	No	—
	M	2.00	S–M = —.06	.617	.6	No	—
W	S	2.20	S–H = .18	2.67	.02	Yes	S
	H	2.02	H–M = —.33	5.00	.001	Yes	M
	M	2.35	S–M = —.15	2.57	.02	Yes	M
P	S	1.85	S–H = .22	1.57	.2	No	—
	H	1.84	H–M = —.25	3.55	.01	Yes	M
	M	1.84	S–M = —.03	.30	.8	No	—
He	S	2.26	S–H = .01	.096	1.0	No	—
	H	2.04	H–M = 0.	0.	1.0	No	—
	M	2.29	S–M = .01	.124	1.0	No	—
Average of all subjects	S	2.07	S–H = .117			Yes	S
	H	1.95	H–M = .192			Yes	M
	M	2.14	S–M = —.075			No	—

* S = soft, H = hard, M = medium surfaces

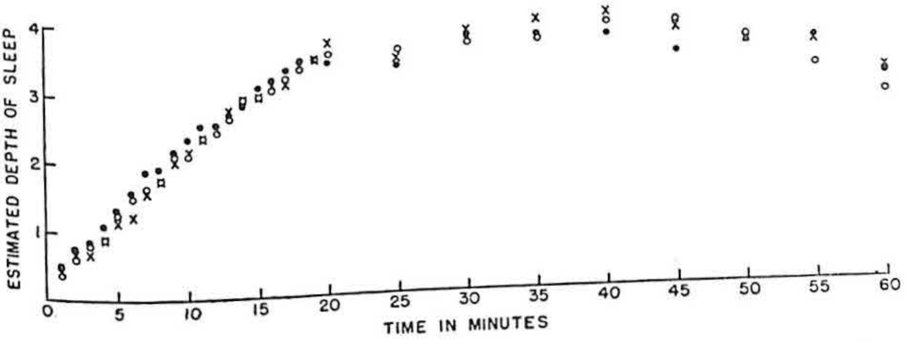

FIG. 6. AVERAGE ESTIMATED DEPTH OF SLEEP OF ALL 4 SUBJECTS ON EACH OF THE SUPPORTING SURFACES DURING THE FIRST HOUR OF THE SLEEP PERIOD. ○○○ = *soft*; ××× = *medium*; ●●● = *hard surface.*

their sleep on the three surfaces in widely different ways; thus the range of scores for one subject rarely varied by more than 5 units, while for the others the scores on different nights differed quite markedly. However, the data obtained do show that the subjects were aware of differences in the supporting surfaces and expressed quite definite opinions concerning the effect of the surfaces on their sleep. Thus all of the subjects rated the hard surface lowest of the three possible choices (table 2), and the 4 subjects treated as a group, showed a significant preference for either the soft or medium surface over the hard (table 2). On the other hand, when the subjective estimates of the individual sleepers are analyzed (table 2) it can be seen that there is no consistent relationship between the statistically significant preferences based on the estimated depth of sleep and those based on the subjective estimate of the sleeper. This failure of correlation is probably due to differences in basis of evaluation and should not bring into question the basic claims of objective measurement.

TABLE 2

Subjective estimate of sleep

SUBJECT	AVERAGE VALUE PER SURFACE*		DIFFERENCE BETWEEN SURFACES				
			Difference*	t	$p<$	Significant	Preference
Ho	S	85.6	S–H = 30.5	3.66	.01	Yes	S
	H	55.1	H–M = —29.1	3.79	.01	Yes	M
	M	84.2	S–M = 1.4	.348	.8	No	—
W	S	62.9	S–H = 1.0	.297	.8	No	—
	H	61.9	H–M = —3.1	.881	.4	No	—
	M	65.0	S–M = —2.1	.612	.6	No	—
P	S	97.4	S–H = 27.2	8.69	.001	Yes	S
	H	70.2	H–M = —27.6	8.88	.001	Yes	M
	M	97.8	S–M = —.4	.89	.4	No	—
He	S	63.6	S–H = 4.2	.383	.8	No	—
	H	59.4	H–M = —28.6	3.06	.02	Yes	M
	M	88.0	S–M = —24.4	3.75	.01	Yes	M
Average of all subjects	S	76.2	S–H = 15.9			Yes	S
	H	60.3	H–M = 19.0			Yes	M
	M	79.3	S–M = 3.1			No	—

* S = soft, H = hard, M = medium surfaces

A somewhat similar picture is presented by analysis of the movement of the various sleepers during the night. In all cases the average number of moves was greatest on the hard surface (table 3) and results for the group of subjects revealed a real preference for either the soft or medium over the hard surfaces (table 3). However, as in the case of the subjective estimate, there was no consistent correlation between the significant results for individual sleepers based on movement and those based on estimated depth of sleep or subjective judgement.

TABLE 3

Number of moves/5 minute period

SUBJECT	AVERAGE VALUE PER SURFACE*		DIFFERENCE BETWEEN SURFACES				
			Difference*	t	$p<$	Significant	Preference
Ho	S	.602	S–H = —.217	1.75	.1	No	—
	H	.819	H–M = .263	2.22	.05	Yes	M
	M	.556	S–M = .046	.417	.7	No	—
W	S	.498	S–H = —.061	1.17	.3	No	—
	H	.559	H–M = .117	2.16	.05	Yes	M
	M	.442	S–M = .056	.919	.4	No	—
P	S	.258	S–H = —.283	6.79	.001	Yes	S
	H	.541	H–M = .208	3.76	.01	Yes	M
	M	.333	S–M = —.075	1.70	.2	No	—
He	S	.536	S–H = —.006	.100	1.0	No	—
	H	.542	H–M = .174	3.33	.02	Yes	M
	M	.438	S–M = .168	3.54	.01	Yes	M
Average of all subjects	S	.501	S–H = .147			Yes	S
	H	.648	H–M = .208			Yes	M
	M	.444	S–M = .057			No	—

* S = soft, H = hard, M = medium surfaces

The results of studies of average heart rate are shown in table 4. As might be expected from the results described above, the heart rate was practically identical on all surfaces for each of the 4 subjects. Temperature studies were similarly unrevealing, the only positive result being a suggestion that this value was higher when the sleeper was on the soft surface. If the soft surface tended to envelop the extremities more than the other two surfaces, such a result would be expected. Only one other point should be mentioned. In spite of the apparently completely unyielding nature of the hard surfaces, none of the subjects made any strong complaints about spending one night out of three on a plywood board and none suggested that such a sleeping surface had an adverse effect on ability to perform usual daily tasks. Whether or not different results would have been obtained if the subject had been required to spend a large number of consecutive nights on this surface cannot be decided on the basis of these studies.

TABLE 4

Average heart rate, beats/minute

	SUPPORTING SURFACE		
SUBJECT	Soft	Hard	Medium
Ho	65.8	66.5	66.1
W	63.3	63.5	63.6
He	57.6	56.9	56.9
P	59.4	57.8	57.6
Average of all subjects	62.6	62.4	62.4

DISCUSSION

The results obtained in this study of the effect of three different supporting surfaces on several aspects of sleep bring up a number of questions which require additional elucidation. In the first place, while it is evident from the results of estimated depth of sleep, subjective estimate and body movement that the various surfaces did influence the character of the sleep obtained, it was not possible to evaluate the importance of the apparently small differences noted. In time small differences might create more obvious advantages. The change in average depth of sleep, if multiplied by the duration of the sleep period, indicates that at least for some individuals there was a substantial difference in the total quantity (depth times duration) of sleep on certain surfaces. It is not known whether this change in quantity of sleep has any significance in terms of the overall well-being of the individual. The poor correlation between subjective estimate and estimated depth of sleep might imply that it has none. Similarly, although there was a reasonable difference in the number of moves on the different surfaces, it appeared in this study, as in previous work (Hoffman *et al.*, '56; Brooks *et al.*, '56 and Kleitman, '39), that there was little relationship between average depth of sleep and number of moves during the night. Although there was a somewhat more consistent relationship between movements and subjective estimate than between movements and sleep depth, even in the former case it would appear that the sleepers' estimate is influenced strongly by factors other than body movement during sleep. The consistency of the heart rate under all three test conditions is not surprising in view of the fact that it is only an insensitive index of changes in depth of sleep. Finally, it should be emphasized that there is no information available concerning the actual advantages to the sleeper of a higher or lower value for any of the variables studied. In this sense, then, no conclusions concerning the effect of the supporting surfaces on the *quality* of sleep can be attempted. However, there are two positive results of this study. In the first place, it has been demonstrated that individuals differ considerably in their sensitivity to supporting surfaces. Secondly, quantitative differences were seen and though no conclusions concerning quality and beneficial effect can be substantiated at this time, it can be said that some of the subjects definitely slept less well on the very hard surface and one slept less well on both the hard and soft, than on a medium supporting surface. In certain circumstances these small advantages and disadvantages might be magnified.

SUMMARY

The EEG, heart rate, body movement, and skin temperature of 4 subjects sleeping on three different (hard, medium, and soft) supporting surfaces have been studied and the subjective estimates of the sleepers recorded. The use of sound stimuli has been found of considerable value as an aid to the identification of the depth of sleep from the EEG records. As in previous studies, a good inverse relationship has been found between moment to moment changes in heart rate and sleep depth. However, this relationship is not quantitatively the same throughout the night, and the average heart rate is not related to the average depth of sleep. The relationship between movement and depth of sleep is somewhat similar to that for heart rate. Factors other than depth of sleep are of importance to the control of these variables. On the basis of the studies performed, it can be said that the hard surface did have an effect on depth of sleep, movements, and the subjective estimate of sleep. However, the differences in these variables were not large and were not always statistically significant. Subjects varied in their sensitivity to changing firmness of supporting surfaces.

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BOOK REVIEWS

Body-Build, Body-Function, and Personality. Edited by BENGT LINDEGÅRD. 132 pp. Lunds Universitets Årsskrift. N. F. Avd. 2. Bd 52. Nr 4. 1956. No price indicated.

The editor, who is also the author or co-author of all the 6 papers making up the volume, is in charge of the Laboratory of Differential Somatology, associated with the Department of Anatomy, University of Lund, Sweden. For some time he has been carrying on, industriously and with imagination, studies on individual differences. As the subtitle of the volume indicates, these are reports on different aspects of "Medical anthropological investigations on 320 Swedish 20-year-old healthy army men." This defines the sample. How about the content?

The system for a quantitative assessment of body-build, described in detail in an earlier monograph,* is briefly presented in the first paper ("Differential Morphology"). It operates with variables chosen as to reflect individual variations in (1) body length (length of radius and tibia), (2) skeletal sturdiness (condylar breadths—femoral, tibial, bimalleolar), (3) muscular development (from dynamometric data on grip strength, shoulder thrust, and shoulder pull), and (4) adiposity (evaluated as a "residual," on the basis of body weight or extremital girths, keeping other relevant body-build "factors" constant, or from skinfolds).

A study, concerned with fat distribution and utilizing skinfolds measured at 10 sites, suggests the presence of a continuous interindividual variation as regards the proportion between truncal and extremital deposits of subcutaneous fat (B. Škerlj's Truncic-Extremital Vector; Am. J. Phys. Anthropol. (n. s.), 11, p. 591, 1953). Muscularity, assessed by dynamometric recordings, was examined in reference to physical activity and selected male sex characters, such as genital size and hairiness of the trunk, were examined—with some unexpected results, such as hairiness being positively related to fatness—in reference to general body-build, endocrine activity, and personality. The relationship between some steroid substances excreted in the urine of adult males were subjected to biometric analysis and the interrelations between somatologic, endocrine and psychological variables were studied in detail.

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* Variations in Human Body-Build. By Bengt Lindegård. Acta Psychiatr. Neurol., Suppl. 96. E. Munksgaard, Copenhagen, 1953.

Space does not permit a detailed critical appraisal of the author's system of *differential somatology* and his exploration of the co-variation with other somatologic, biochemical, and behavioral characteristics. The interdisciplinary approach, involving the collaboration of endocrinologists (S. Genell, C. C. Jensen) and students of personality (G. E. Nyman, a psychiatrist) is in the best tradition of human biology. The system of presenting the basic variables ("factors") in the form of a "body-build diagram," with group means as reference points and standard deviations as units of measurement, while firmly established in psychology, in the form of ability or personality "profiles," is new in physical anthropology (*cf.* S. M. Garn, Ann. N. Y. Acad. Sci., *63*: 537-552, 1955). Lindegård's search for a more meaningful expression of somatic variables and his use of "residuals," *i. e.*, differences between the actual value of a measurement, such as body weight, and the value predicted from the correlated dimensions, such as those indicative of body length, deserves notice.

This does not mean, however, that the proposed system should be swallowed in its totality—hook, line, and sinker—by anthropometrists still hungry for a workable system of quantitative description of human physique or that this reviewer is celestially happy with all other aspects of the work by Lindegård and his co-workers, including the assessment of personality in terms of four variables, labelled "capacity," "validity," "stability," and "solidity," and rated on a 7-point scale on the basis of short, single interviews.

It is unfortunate that Lindegård was not familiar with the far-reaching ideas of J. Matiegka (Am. J. Phys. Anthrop., *4*: 223-230, 1921) who was motivated by that same healthy discontent with the existing systems for the characterization of human physique and who presented a scheme for describing body build in terms of relative amounts of muscle and adipose tissue, with skeletal weight as the reference point. Quantitatively oriented anatomists owe Matiegka a debt, still largely unpaid (except for Mildred Trotter's work on the estimation of skeletal mass; Am. J. Phys. Anthrop., (n. s), *12*: 537-551, 1954), of replacing Matiegka's approximative constants by rigorously derived estimation equations, especially of the total amounts of muscle in the body.

The combination of performance criteria used in assessing "muscularity" with morphological criteria, which are the basis for a quantitative appraisal of skeletal "length" and "sturdiness," is undesirable. It must be recalled that performance, including voluntary muscle contractions, is a "product" of capacity (a physiological concept, related to muscle size) and motivation. Only when the latter is "constant," preferably maximal, can actual performance serve as indicator of capacity and, in turn, of muscular development. This condition was probably fulfilled in Lindegård's series but can not be postulated as being present in all situations. Furthermore, such a mixture of approaches is not necessary. Measurements of the circumferences of the extremities together with skinfolds determined at the same level (with femoral condyles and a length factor added for good measure) provide an adequate indicator of muscular development, at least for the extremities.

The separate pagination of individual papers, and consequent absence of a table of contents or an index, does not make for efficient use of this valuable and stimulating volume.

JOSEF BROŽEK

University of Minnesota,
Minneapolis, Minn.

Radiographic Atlas of Skeletal Development of the Knee: a Standard of Reference. By S. IDELL PYLE and NORMAND L. HOERR. 82 pp. Charles C. Thomas, Springfield, Illinois, 1955. $4.25.

The heaviest single bone in the human body is the femur. Most of its elongation occurs at the distal end, at an epiphysial site which can readily be studied in children from radiographs of the knee. The atlas of Pyle and Hoerr now enables us to trace the skeletal development of this region from infancy to maturity.

This atlas is based on nearly 30 years of research on developmental radiographs of the skeleton which have been accumulating at Western Reserve University. These monumental studies were initiated by the late Professor T. Wingate Todd. It was he who directed the growth study of the Brush Foundation in Cleveland, Ohio through its first decade, and published his *Atlas of Skeletal Maturation* (*Hand*) just before his death in 1938. This was an interim atlas, based largely on cross-sectional surveys of Cleveland children from both poor and prosperous environments. Todd's successor, Dr. Walter W. Greulich, continued the direction of the Brush Foundation study. In 1950, he and Dr. S. I. Pyle produced a more definitive atlas of the hand. The Greulich-Pyle atlas is now used for developmental assessments in many parts of the world. It is based on selected Cleveland children, reared under economically favored conditions and in optimal health. These children were relatively free from the stresses of malnutrition, illness and climate which impede the growth of much of mankind, and the Greulich-Pyle standards therefore present an idealized picture of rapid and regular skeletal development.

Nearly all of the films in the Pyle-Hoerr atlas of the knee are also based on children from the Brush Foundation study, with optimal histories of health. The book contains 57 films of the knee, which were very carefully culled from an original series of 10,700. Some of the children were followed for as little as two years, and others for as long as 12.

The Greulich-Pyle atlas of the hand has separate sets of standards for boys and girls, but the Pyle-Hoerr atlas has a single set of films of the knee for both sexes. Girls undergo more rapid skeletal maturation than do boys however, so that after the first few postnatal weeks, each film has a younger developmental age equivalent for girls than for boys. Up to 6 years of age, and from 10 to 12 years, an average girl at a given stage of ossification of the knee is about 80% as old as a corresponding boy. From 7 to 9 years, she is at about 70% of the boy's age. Prior to adolescence, these percentages may be of use in estimating the age and sex of immature skeletal remains from bones and teeth, as outlined in 1955 by Hunt and Gleiser (Am. J. Phys. Anthrop., n. s. *13*: 479-488).

In practice, the problem arises as to whether skeletal age should be assessed from both hand and knee in an individual child. For the hand, one film is enough for a single assessment, while for the knee at most ages it is desirable to have both a mediolateral and a postero-anterior film. In routine work, the knee usually fails to add much to what a careful study of the hand can tell us. But if the clinician or investigator has special reasons for studying the developmental normality of the lower limb, he should certainly use the Pyle-Hoerr atlas. It is a product of years of devoted labor, and is deserving of high praise.

EDWARD E. HUNT, JR.

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Psychology, Evolution and Sex. By CECIL P. MARTIN. xiii + 166 pp. Charles C. Thomas, Springfield, Illinois. 1956. $4.75.

Professor Cecil P. Martin, of McGill University, is an anatomist who has grave suspicions about conventional genetic theory. Once before he issued a minority report (Martin '53), and now he does it again, in a book that has the most eye-catching title in recent memory.

Geneticists, says Dr. Martin, worship the orthodoxy of the "mutation-selection" theory, explaining away all that does not square with it, yet rejecting evidence to the contrary, and ignoring theories not contained within the several ideas of particularate inheritance, isolation of the genic material from environmental influences, natural selection, and mutation. Not quite a Lamarkian, and too much a naturalist to offer an *élan vital*, Martin assembles citations to prove "lingering modifications" (*Dauermodifikation*) and offers his own theory of why sex is important. Throughout, the argument is directed against what he thinks geneticists think, and that is why the objects of the objections are often so elusive.

Now the study of evolution is an evolving science where the heterodoxies of one era become the orthodoxies of another. The early post-Darwinian age of acceptance gave rise to the era of scepticism, and this in turn yielded to the *Genetical Theory of Natural Selection.* New ideas are to be welcomed; we still have much to learn about evolution. But Dr. Martin's ideas are a curious blend of last-century objections and half-understood concepts, both better illustrated than described.

Mutations, he says, are pathological conditions. Why? Because known mutagens, such as nitrogen mustard and penetrating radiation are exceedingly injurious. What happens, he argues, is that the genes or "particles of the genes" are agitated, much as violent agitation can dislocate a man's thumb. And from this line of anthropomorphic reasoning, it is not difficult for him to decide that *all* mutations (being injuries) are harmful, whereas such characters as seem to be adaptive are simply examples of "lingering modifications." Ergo, as stated on page 81 ". . . I fail to see how the mutation-selection theory can be defended."

As promised, psychology is drawn in, that is, the psychology of what used to be called instinctive behavior. Martin correctly cites many instances where the feeding preferences of a form have been modified by rearing the young on a non-preferred plant, on an unaccustomed diet. Such examples, he feels, show that preferences can be modified and the new preference then becomes hereditary. The rest of us would see here the effects of learning: increasingly much of what used to be called instinctive, now appears to be learned. Even such seemingly basic "instincts" as the nesting instinct in the pregnant rat, or the "grooming" instinct depend upon the previous experiences of the animal in question. So the whole argument about the modification—and—inheritance of behavior dissolves into a simple exercise in learning theory.

As to sex, Martin rejects the conventional explanations. The idea that new genotypes are thus produced is insufficient for him; "shuffling the genes destroys gene-complexes just as fast as it creates them." (This, of course, is not at all true.) But his explanation for the survival of sex involves "its usefulness as a restriction on the transmission of the prejudices, aversions and partialities of parents to their offspring." For an understanding of this explanation, the book must be read.

The real value of the present work lies in the large number of rarely-quoted minority reports he cites. They include the work of Kammerer, whose unfortunate history Martin does not recount, and other publications where modifications were claimed to persist for many generations. They include, also, accounts of the reversion of domesticated lines to "wild" types, and others where hereditary traits are shown to persist only on a particular diet. (They do not include references to DeLamarck, whose inferences that the peculiarities of domesticated animals and plants are due to nutrition, are at least partly correct.)

What *Psychology, Evolution and Sex* does show, is the increasing difficulty of tackling one field, with the conceptual tools and references of another. Despite Martin, the autopsy table is not a proving ground for genetical theory, nor does embryological similarity prove that no new evolutionary characters have entered into pre-natal development.

STANLEY M. GARN

Fels Research Institute,
Yellow Springs, Ohio

Anxiety and Stress: An Interdisciplinary Study of a Life Situation. By H. BASOWITZ, H. PERSKY, S. J. KORCHIN, AND R. R. GRINKER. xv + 320 pp. McGraw-Hill, New York, 1955. $8.00.

In 301 pages of text, figures, and tables, a longitudinal study of some biochemical and psychological responses of parachute trainees is presented in meticulous and overwhelming detail. The subjects are healthy, highly selected individuals, and are keenly motivated to acquire the status of a parachutist. These facts alone almost completely destroy the effectiveness of the research. The trainees simply are not made very anxious by the training program, although tower-jumping and airplane-jumping may evoke increments of anxiety. "Free anxiety," however, is not "released" in large amounts, and the low degree of anxiety evoked is related more to fear of failure than to fear of bodily harm. With an integrity and determination that leaves this reviewer awed, the Michael Reese group nevertheless persevered through the execution of a series of small-sample studies of "anxiety and stress." To their credit, they do wring out of a mass of data some suggestive hypotheses, and a few clear findings.

The psychological measures (anxiety questionnaire, elaborate ratings of interview materials, tachistoscopically administered Bender-Gestalt test, serial subtraction, perceptual closure of incompleted circles presented tachistoscopically, memory for digits, and scores on a story-telling test using presumably anxiety-provoking pictures relevant to parachute training) were selected a priori and empirically. The lack of clear-cut conceptualization and theoretical focus is unfortunate.

The biochemical aspects of the study stem from a previous finding that hippuric acid excretion is high in highly anxious patients. This variable is the focus of the biochemical research. The other variables measured (plasma glycine level, plasma amino acid level, blood reduced and oxidized glutathione levels, eosinophile counts, and hematocrit) were introduced either in an attempt to explore the precursors of hippuric acid excretion, or to add information about adrenocortical response.

Decisively positive findings are few. Change in glutathione level appears to be an important biochemical stress response, intermediate between the overly sensitive eosinophile response and the insensitive hippuric acid response. Of the psychological variables, perceptual adequacy showed promise, and sometimes effectiveness, as a correlate of rated anxiety and of the stressfulness of activity. The pioneering study of intra-individual variability included in this report should stimulate research in this sadly neglected area.

This monograph, to the reviewer's mind, is a report for specialists only, who are interested in technical details, and who are willing to tolerate the lengthy presentation of many negative, or only suggestive and provocative, results. The non-specialist is likely to end the book with the correct conviction that biochemistry, psychology, and psychiatry, either independently, or in partnership, have not forged either tools or concepts able to cope with the complexities of the interrelated responses of the "total organism" to a "life situation." The book ends with these words: "The gain from the work has been less in increasing our knowledge of the details of psychosomatic problems and more in learning the complexities of psychosomatic organization and integration. The problem of anxiety is still *non liquet*, but perhaps we know a little more about why this is so."

JOHN I. LACEY

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Population Theory and Policy: Selected Readings. Edited by JOSEPH J. SPENGLER AND OTIS DUDLEY DUNCAN. x + 522 pp. The Free Press, Glencoe, Illinois, 1956. $7.50.

One of the problems of a field like demography, overlapping so many areas of the social and biological sciences, is the inevitable scattering of its literature through an assortment of unrelated journals. This makes it difficult for both the classroom student and the general reader to obtain convenient access to what is published. The volume under review is one of two that should help to repair the situation, though its contents will for the most part be more appropriate for advanced than for beginning readers in the subject.

The 38 articles, with 78 pages of footnotes, are organized into 9 chapters, each of which begins with a brief introduction by the editors. The chapters are: Development of population theory; The role of theory in population studies; Theory of population growth; Population, resources, technology, and levels of living; Population and level of economic activity; Population growth and economic development; Population growth and international relations; Socio-cultural context of population dynamics; and Population policy. With a very few exceptions, the material has been chosen from the writing of American authors, about two-thirds of it from publications of the last 10 years. The volume closes with a 9-page bibliography of recent works in English. The companion volume, *Demographic Anaylsis: Selected Readings*, reviewed elsewhere in this journal, presents some of the specific findings of demographic research, but neither of the two books consider in detail the analytical techniques of the field.

The general reader whose major interest lies in biology will probably not wish to read the whole book, but he will find it interesting to look through the volume to gain an idea of some of the lines of thought now being explored in demography. He may be struck in particular by the weight given to economic aspects of the problems considered. This is a reflection of the fact that although demography is often thought of in this country as more nearly a branch of sociology than of any other discipline, a great deal of the theorizing in the field has been done by economists. Direct attention to biological topics is quite rare in this volume and consists in part of a history of dubious analogies. Demography has still some progress to make in the effective use of biological information.

A few of the articles may be mentioned as likely to be of especial interest to readers of this journal. The three articles in the first chapter on the development of population theory contain a number of references to ideas of biology. Material from a variety of specialized areas is imaginatively drawn together in Boulding's "Toward a general theory of growth." Lotka's "Some recent results in population analysis" illustrates a major branch of demographic activity, while Davis' "Population and power in the free world" has broad general interest.

The chapter on population theory leaves something to be desired. A general coverage of important points of view in this area should include, for example, an exposition of the Marxian position which must be taken into account (even when it is not accepted). A more comprehensive description and assessment of policy measures affecting population in various countries would also add to the completeness of the presentation.

GEORGE F. MAIR

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Northampton, Massachusetts

Demographic Analysis: Selected Readings. Edited by JOSEPH J. SPENGLER AND OTIS DUDLEY DUNCAN. xiii + 819 pp. The Free Press, Glencoe, Illinois, 1956. $9.50.

This lengthy companion volume to *Population Theory and Policy* contains a total of no less than 63 articles selected from 25 different journals and other more inaccessible sources. Although there are a number of selections of particular relevance for the student of biology, the orientation of the collection is revealed by the predominance of sociologists and economists among the contributors.

The volume is admittedly not, as its title might suggest, designed to be a "do-it-yourself" guide to the methodology and analytic techniques of demography. The basic criterion for the inclusion of an article was presumably that it illustrate both the demographer's approach to population data and the types of research problems that are posed. The book is divided into 7 sections, each introduced by brief organizing editorial remarks. The broad range of subjects covered includes the conventional topics of past and future population trends, mortality, fertility, international and internal distribution of population and migration, and population composition. The volume concludes with a series of papers describing the recent demographic histories of over a dozen countries and areas throughout the world. The section of most direct interest to the biologist is Chapter VI (population composition), which includes 5 selections on population quality. The primary concern of these articles is with the presumed genetic consequences of population change, particularly differential fertility. In this context the subject of the future intelligence levels of the population is reviewed. These selections strikingly reveal the primitive level of measurement criteria in eugenics although they indicate no dearth of opinions.

An evaluation of a volume such as this is not simple. Certainly the value of each contribution cannot be appraised individually. The conventional standards that remain, therefore, are the selections included, the editorial skills evidenced in the introductory sections, and the potential usefulness of such a book. The strongest feature of the book is the high quality of the choices made by the editors. On the whole, the articles reprinted are excellent both in the sense of illustrating the methodological approaches of demography and of assembling in one source some of the most important findings of demographic research. Occasionally the reader will feel uncomfortable in the presence of assumptions made about the inevitable stabilization or decline of the United States population contained in articles written over ten years ago when such assumptions were fashionable. However, it provides one with an interesting picture of the profession's self-consciousness as revealed in Harold Dorn's excellent critical review of population forecasting.

The editors' introductory materials are not sufficiently long to provide the kinds of coherence and organization that might be desirable. The value of the book rests squarely on their wise choice of materials rather than the connective tissues they superimposed.

The usefulness of the volume will, I believe, be quite limited owing both to its price and the fact that the materials are more suitable for the graduate student and professional than for the undergraduate. Although its usefulness to the biologist is even more limited, the book can be regarded as an excellent source book of demographic research classics.

CHARLES F. WESTOFF

Office of Population Research,
Princeton University

Non-parametric Statistics for the Behavioral Sciences. By SIDNEY SIEGEL. 312 pp. McGraw-Hill, New York, 1956. $6.50.

This book forms a valuable addition to the McGraw-Hill Series in Psychology because over half of the text presents detailed information about procedures not described in most of the popular statistics texts. It does so in a very clear manner, illustrating the computations for each procedure by a worked out example and will be useful to workers in many areas of human biology.

Although the remainder of the material may be found in some other books, it is presented here in a novel frame of reference. In fact, perhaps the most useful feature of the text is the strong emphasis placed throughout on the fundamental distinctions between procedures applicable to nominal, ordinal and interval scales. A table, printed on the inside of the front and back covers of the book summarizes the techniques discussed and forms a fine pedagogic device continually reinforcing these distinctions.

The text will be of great help to anyone who wishes to enrich his kit of statistical tools, and should present no difficulties to persons not well acquainted with mathematic statistics. As a textbook it will supplement the various available texts concerned with the better known parametric statistics such as t, F and r. A glossary of symbols, a combined author and subject index, a list of references for further reading and a large number of tables not readily accessible elsewhere enhance the usefulness of the book.

STEVEN G. VANDENBERG

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Ann Arbor, Mich.

BOOK NOTICES

GENERAL SYSTEMS. Edited by Ludwig von Bertalanffy and Anatol Rapoport. 162 pp. Society for the Advancement of General Systems Theory, 1956. (no address, no price) The first yearbook of the Society consists of 3 parts: (1) Introduction (3 papers), (2) Exploration of mathematical models, with special reference to life processes (evolution, growth, individual and group behavior), and (3) "in search of new foci of integration" in biology, psychology and sociology.

FATIGUE, STRESS, BODILY CHANGE AND BEHAVIOR: SELECTED BIBLIOGRAPHY. By William Bevan and Rollin M. Patton. 59 pp. (no price) Military Operations Research Engineering Division, Lockheed Aircraft Corporation, Marietta, Georgia, 1956. An alphabetical listing of some 900 titles, followed by a topical index. The bibliography, covering the years 1946-56, was compiled as part of preparations for experimental investigations on aircrew fatigue.

MOLECULAR STRUCTURE AND FUNCTIONAL ACTIVITY OF NERVE CELLS. Edited by R. G. Grennell and L. J. Mullins. ix + 169 pp. American Institute of Biological Sciences, Washington, D. C., 1956. $4.75. The proceedings of a symposium held in Washington, D. C., on June 3-4, 1955, under the sponsorship of the Office of Naval Research dealing with 3 groups of subjects; (1) receptors (chemoreception, vision), (2) aggregates of neurons, and (3) nerve cell membranes. The publication demonstrates one way in which the Institute can contribute significantly to advancement in biological sciences.

HYPNOSIS AND ITS THERAPEUTIC APPLICATIONS. Edited by Roy M. Dorcus. x + 327 pp. McGraw-Hill, New York, 1956. $7.50. Aims to incorporate in a single volume the theoretical, experimental, and therapeutic aspects of hypnosis. Includes a large chapter on the physiological effects of hypnotic stimulation.

DICTIONARY OF ANTHROPOLOGY. By Charles Winick. vii + 579 pp. Philosophical Library, New York, 1956. $10.00. "A field which includes archeology, cultural anthropology, linguistics, and physical anthropology has boundaries and a vocabulary that are constantly expanding." Cautious souls will regard with uneasiness one man's attempt to master such a wide area. Physical anthropologists will find that the expanding edge of their science is not adequately represented.

PROGRESS IN THE PHYSIOLOGY OF FARM ANIMALS. Edited by John Hammond. v + 330 pp. Butterworths, London, 1957. 50s. ($7.00). The final volume of a comprehensive survey, not lacking wider implications (see *Human Biology*, 28: 278-280, 1956), deals with reproduction (reproduction hormones, female fertility, pregnancy) and milk production.

Medical Effects of the Atomic Bomb in Japan. Edited by Ashley W. Oughterson. xvi + 477 pp. National Nuclear Energy Services, Manhattan Project Technical Section, Division VIII, Vol. 8. McGraw-Hill, New York, 1956. $8.00. Based on a 6-volume report, this book presents a summary of ecological, clinical, hematological, and pathological studies made in Hiroshima and Nagaski following the atomic bombing of the two cities, resulting in mechanical, thermal, and radiation injuries. A "tract for our times," indeed.

Culture and the Structural Evolution of the Neural System. By Fred A. Mettler. 57 pp. American Museum of Natural History, New York, 1956. In this James Arthur Lecture on the evolution of the Human Brain (1955), the author has drawn attention "to the fact that there is no good evidence to support the assumption that man's neural system has undergone any progressive alteration in the direction of greater size or complexity since the middle of the Pleistocene. It was at this period that cultural development became manifest, and the hypothesis is advanced that, with the advent of culture, man achieved a degree of independence from his environment and was therefore no longer under the necessity of developing structural modifications to survive."

Emotional Hazards in Animals and Man. By Howard S. Liddell. xi + 91 pp. Charles C. Thomas, Springfield, Illinois, 1956. $2.50. Six lectures, delivered in Halifax to psychiatric residents of the Royal Victoria Hospital, present the implications of the study of conditioned reflexes, initiated by Pavlov.

Minnesota Studies in the Philosophy of Science, Vol. I. Edited by H. Feigl and M. Scriven. xiv + 346 pp. University of Minnesota Press, Minneapolis, 1956. $5.00. "The first volume of Studies presents some of the relatively more consolidated research of the Minnesota Center for the Philosophy of Science and its collaborators." Some studies deal with the more general issues (including meaningfulness of theoretical concepts) while others are concerned with more specific topics (psychoanalytic theories, radical behaviorism, validity in psychological tests, characterization of a single personality).

Culture and Mental Disorders. By Ralph Linton. vii + 139 pp. Charles C. Thomas, Springfield, Illinois, 1956. $4.50. Examines the relationship of psychiatry to cultural anthropology in 3 chapters concerned with Culture and normality, Cultural influences in neurosis and psychosis, and Homosexuality and the hysterias in cultural perspective.

Social Characteristics of Urban and Rural Communities, 1950. By O. D. Duncan and A. J. Reiss, Jr. xviii + 421 pp. John Wiley, New York, 1956. $6.50. The study deals with characteristics of human populations, analyzed in terms of human ecology (social morphology).

Experimental Design. By Walter T. Federer. xix + 544 pp. Macmillan, New

York, 1955. $11.00. An advanced textbook, growing out of the author's experience as professor of biological statistics at the College of Agriculture, Cornell University.

FRANZ JOSEPH GALL, INVENTOR OF PHRENOLOGY AND HIS COLLECTION. By E. H. Ackerknecht and H. V. Vallois. 86 pp. University of Wisconsin Medical School, Madison, 1956. $1.50. Published as No. 1 of *Wisconsin Studies in Medical History*, the monograph deals with Gall's life and personality, his work as a scientist (in anatomy, psychophysiology, and anthropology), and as a social reformer. His collection (busts, masks, skulls, brains) is described and a special study of a few items, including Gall's skull, is presented.

TECHNIQUES IN BLOOD GROUPING. By I. Dunsford and C. C. Bowley. xiv + 250 pp. Charles C. Thomas, Springfield, Illinois, 1955. $4.50. This practical manual describes the principles of blood grouping, presents systematically the laboratory procedures, and provides a glossary of terms and symbols.

JOSEF BROŽEK

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INFORMATION FOR CONTRIBUTORS

Human Biology, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of $8\frac{1}{2}$ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne State University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

Where possible, illustrations should be made for reproduction as line engravings, hence drawn in India ink as boldly as possible. Lettering must remain legible after figures are reduced to fit on $4\frac{1}{4}$ x $6\frac{3}{4}$ inch pages (letters $1\frac{1}{2}$ to 2 mm high after reduction are adequate). Figures should be numbered consecutively with Arabic numerals. Tables should be numbered independently from 1 up, and both figures and tables should have captions. When the amount of tabular and illustrative material is judged to be excessive or unusually expensive, authors may be requested to pay the excess cost. Galley proofs will be sent to the author and must be returned promptly; when the author makes substantial departures from copy, the cost will be charged to him. Three copies of an abstract (not to exceed 225 words) should be submitted when the proof is returned. One will be sent to the editor of *Biological Abstracts*.

References in the text to the literature should be made by using the author's name followed by the year of publication: " Studies of Garn and Saalberg ('53) . . ." At the end of the article, under the heading " Literature Cited," full references with titles and inclusive page references should appear (double spaced) in alphabetical order of the authors' names: " Garn, S. M. and J. H. Saalberg 1953 Sex and age differences in the composition of the adult leg. Human Biol., *25*: 144-153."

Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the proof has been returned to the press.

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a record of research

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VOL. 29 No. 4

CHANGES IN BODY VOLUME ACCOMPANYING WEIGHT REDUCTION IN COLLEGE WOMEN[1]

BY MARIE L. CARNS AND RUTH B. GLASSOW

University of Wisconsin

THE problem of obesity has long challenged professional groups and has been a cause of concern to laymen. Unquestionably, overall body weight may be reduced by decreasing the caloric intake. At the same time, many people hope for reduction of excess weight in separate areas of the body, such as the thighs, abdomen and arms. Specific exercises are frequently recommended for this purpose. The effectiveness of such exercises lacks the support of controlled studies. It is the purpose of this study to investigate the overall loss of body volume and the comparative loss of volume in body segments when the caloric intake is reduced.

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[1] The data were collected by a graduate student, JoAnn Mann, under the supervision of M. L. Carns, M. D. and E. S. Gordon, M. D., of the faculty of the University of Wisconsin; the study was financed in part by a grant from the Wisconsin Alumni Research Foundation.

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No.

PROCEDURE

Ten undergraduate university women were selected for observation from a group of volunteers on the basis of their degree of excess weight, their interest in the project, and their seeming willingness to cooperate. Attempts were made to select women who were not excessively obese but who could afford to lose approximately 20 pounds in a 6 week period. All had received "A" health grades in the University Department of Student Health. Single determinations of basal metabolism and serum cholesterol were made in each subject; there was no evidence from these tests of any significant thyroid dysfunction.

During a 6 week period the subjects were asked to subsist on the diet planned by Ruth Dickie, chief dietician at the University Hospital where all meals were prepared and eaten. The total dietary intake per day for each woman ranged from 900 to 950 calories. This was apparently adequate for the subjects; all of them reported that they could easily carry on their usual campus activities without a feeling of fatigue or hunger.

Changes in body mass were measured by two methods. One was weight in pounds. Weight was taken prior to the controlled diet period and also at the end of each week of the 6 weeks of the diet program. At each weighing the subjects wore the standard swimming suits used by the Department of Physical Education for Women.

The second measure was body volume determined by the amount of water displaced by the body. A metal cylinder approximately 6 feet in height and two feet in diameter, open at the top, was filled with water to an indicated level. In the tank was a ladder which the subject descended to a specified distance. A stopcock in the tank was opened and water, raised by the immersed body segment, was drawn off to bring the water in the tank to its original level. Thus the water drawn from the tank was equal in volume to the volume of the immersed body segment. The amount was determined by weighing. The temperature of the water was kept at approximately 80° F. The measurements on each subject were always taken at the same time of day.

In order to obtain the volume of separate segments of the body, 6 anatomical points were chosen to locate division lines. These were: A, the apex of the fibular head; B, the gluteal fold; C, the greater trochanter of the femur; D, the inferior border of the twelfth rib; E, the ninth thoracic vertebra; F, the seventh cervical vertebra. At each of these points, an aluminum marker was attached with adhesive tape before the subject entered the tank. The letters A through F are used to indicate division lines and also to designate body segments. In referring to segments, a letter represents the division immediately below the division line. The volume was determined for each body segment. The hands and arms were kept out of the water until the F readings were taken. F segment, therefore, includes the upper trunk and the arms and hands. (See figure 1.) The sum of the 6 volumes measured on the same day represents the volume of the entire body up to the F marker.

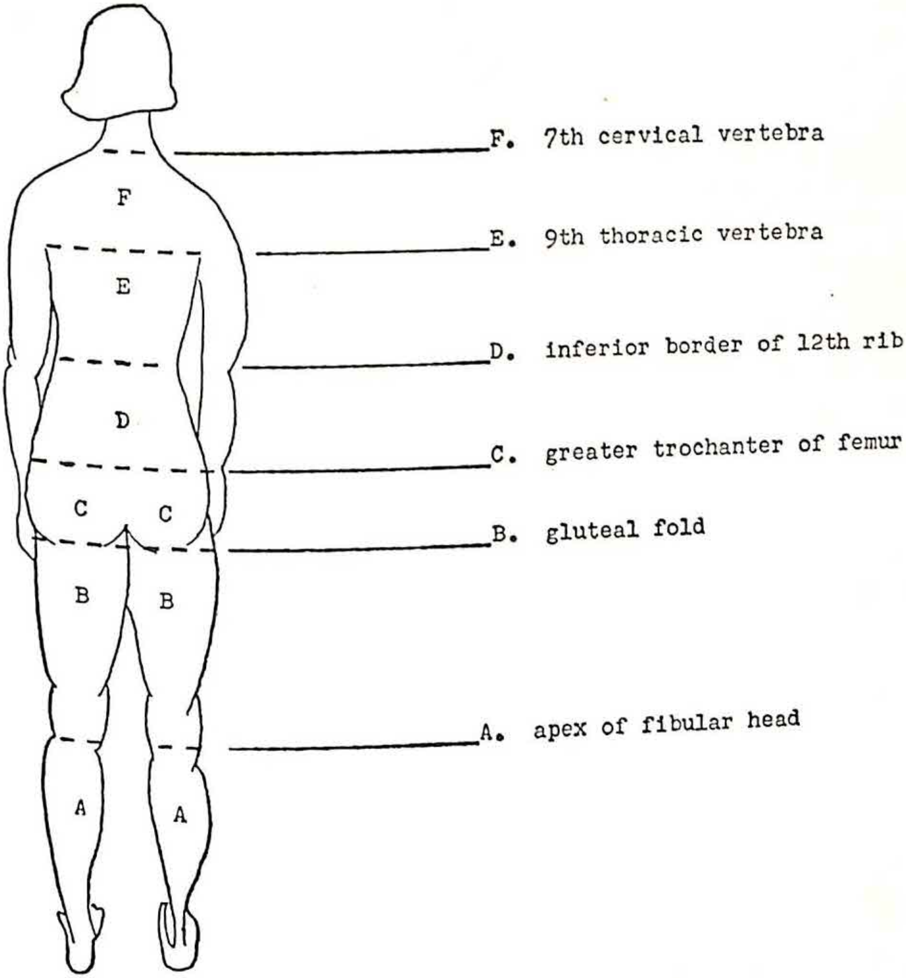

FIG. 1. BODY SEGMENTS AND DIVISION LINES.

All division points except D and E were located by palpation or inspection or both. Points D and E were located in the first of the weekly measures by the above procedures. At this time, the distance from the adjoining marker was measured and in the succeeding weeks D and E were located by referring to the previously determined distances.

At the end of the 6 weeks of observation there were available for each subject (1) measures of body weight, in pounds, taken before the controlled diet period and at the end of each week of the experimental period; and (2) amounts of displaced water for each of the 6 body segments, measured at the end of each week of controlled diet. The latter measures were in pounds of water.

RESULTS

1. *Loss in Body Weight and Total Volume.* Body weight and water weight taken at the end of the first week were selected for comparison with succeeding measures. The percentage of loss for each variable is tabulated in table 1. If no measure was obtained at the end of the first or final week, the percentage has not been calculated. Thus, the volume changes for subjects I and V are not in table 1.

It will be noted that the decrease in volume scores is approximately twice as much as the loss in weight scores. Weight losses range from 5% to 9%; volume losses from 9% to 19%. Note that the volume loss for subject X is not included in this range. It seems probable that some error in the first set of measures for subject X resulted in a reading which appears to be inconsistent with the other measures on subject X and also inconsistent with measures of the other subjects.

Average percentage losses are shown graphically in figure 2. The values are the averages of the losses of subjects in II, III, IV, VI, VII, VIII, and IX. The average percentage loss for volume at the end of 6 weeks for the 7 subjects was 14.7. For the same period, the average percentage loss in weight was 7.6. This is the only presentation of data which does not include the 10 subjects.

2. *Group Segmental Losses.* Table 2 shows the average loss for each segment, the range of these losses, and the rank of each segment according to average loss. The segments may be grouped according to the amount of loss, *i.e.*, low (A and E); medium (B and C); and high (D and F). The averages provide a basis for comparison of individual losses. Note that the range for segment D (17.5-20.9) is

TABLE 1

Weekly decrease in volume and weight

SUBJECT		WEEK-KG.	1ST	2ND	3RD	4TH	5TH	6TH	TOTAL LOSS
			PERCENTAGES						
I	Volume	52.6	—	—	—	—	—	—	—
	Weight	59.9	100	98	97	95	94	92	8
II	Volume	63.5	100	97	94	91	88	86	14
	Weight	74.4	100	97	95	93	92	92	8
III	Volume	48.1	100	97	92	90	85	84	16
	Weight	59.9	100	97	95	94	93	93	7
IV	Volume	56.7	100	98	94	92	84	83	17
	Weight	64.0	100	97	96	94	92	91	9
V	Volume	—	—	—	—	—	—	—	—
	Weight	69.9	100	98	97	94	94	93	7
VI	Volume	56.2	100	97	—	92	89	86	14
	Weight	62.6	100	99	97.8	96	94	93	7
VII	Volume	58.1	100	94	91.8	86	85	81	19
	Weight	62.6	100	97	95.6	93	91	91	9
VIII	Volume	58.5	100	98	98.7	95	92	86	14
	Weight	66.7	100	99	96	94	93	92	8
IX	Volume	56.2	100	96	94	92.8	94	91	9
	Weight	57.6	100	98	97	97	96	95	5
X	Volume	74.9	100	82	75	73	72	—	28
	Weight	67.1	100	97	95.9	95	92	91	9

Volume (up to seventh cervical vertebra) in kilograms of displaced water. Weight in kilograms, total body.

Note: both volume and weight were measured in pounds and, to conform to the policy of this periodical, converted to kilograms.

TABLE 2

Average percentage volume losses per segment

SEGMENT	AVERAGE LOSS	RANGE OF LOSS	RANK
A	12.8	9.6–15.2	6
B	16.9	12.1–24.2	3
C	16.7	14.8–21.8	4
D	19.0	17.5–20.9	2
E	13.7	9.2–18.2	5
F	20.3	15.2–24.7	1

close to the average (19.0) and that the individual differences in segments B and F are greatest.

3. *Individual Segmental Losses.* The weight of the water displaced by one segment is a percentage of the weight of the total amount of displaced water and can be considered a volume percentage of the total body volume. The differences in segmental percentages for the initial and final measures indicate changes in body proportions. In table 3 are listed for each subject the greatest segmental differences (in percentages) and the area in which these differences were found. At the time of the initial measurement, two investigators estimated the area of greatest fat deposit. Except for subject IV, the area of greatest

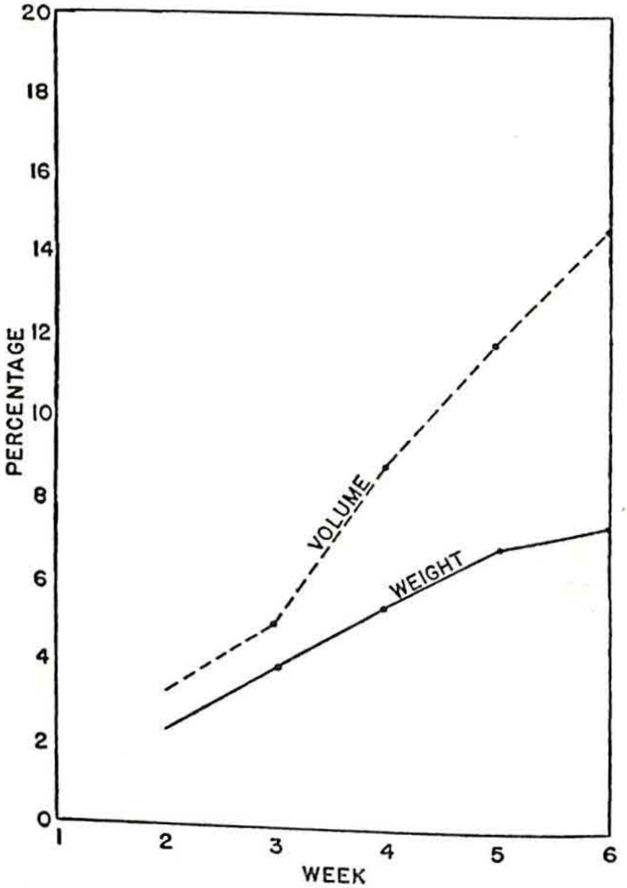

Fig. 2. Weekly Percentage Losses—Average for Seven Subjects.

proportional loss is the one which the experimenters identified as that of the greatest initial fat deposit. It will be noted that the area of greatest loss for subject IV is E which is immediately above D, the area which was subjectively ranked as the area of greatest fat deposit.

TABLE 3

Segmental changes in relation to total volume

SUBJECT	GREATEST DIFFERENCE IN PER CENT	AREA	AREA OF GREATEST FAT DEPOSIT
I	3.1	F	F
II	3.1	B	B
III	1.6	C	C
IV	3.0	E	D
V	3.3	E	E
VI	2.3	C	C
VII	1.9	D	D
VIII	2.7	E	E
IX	1.6	D	D
X	3.8	E	E

TABLE 4

Average segmental percentage of total volume

SEGMENT	INITIAL	FINAL
A	12.8	13.2
B	18.2	18.8
C	16.3	16.0
D	18.7	19.4
E	13.5	11.7
F	20.0	20.4

4. *Changes in Body Proportions.* Another aspect of the changes in body proportions is shown in table 4 which presents the average volume percentage of the total volume.

The greatest average change in body proportions is shown in segment E. (Table 3 shows that this was the segment in which the greatest number of individuals had the greatest loss.) Negligible change in the same direction was present in segment C. It is interesting to note that segment F, which was the area of greatest average loss in volume, retains the same proportion of the total body volume at the time of the first and final measures.

The range of these segmental percentages is also of interest. These are shown in table 5.

TABLE 5

Range of individual differences in segmental volume

SEGMENT	INITIAL MEASURE	FINAL MEASURE
A	4.9	3.3
B	6.4	6.5
C	7.6	6.8
D	3.5	8.2
E	8.8	11.4
F	8.1	4.5

The range of proportions of segments B and C have changed little; the proportions of segments A and F are more alike in the final measures than they were in the first measures and segments D and E are less alike in body proportions than they were before the dieting period.

COMMENT

No statistical evidence of the significance of findings has been attempted. In the writers' opinion, the significance of the observations lies in the fact that all subjects conform to the general findings: the percentage loss of volume is twice that of the percentage loss of weight (the one exception is attributed to measurement error); the area of greatest loss is that of greatest fat deposits (the one exception is attributed to error in subjective evaluation). The evidence suggests that these are physiological phenomena.

The implications which this study has for future investigations are more significant than the specific information on the amounts of local and total volume reductions. The implications seem to the authors to be twofold.

First, those professions which attempt to stimulate interest in reduction of fat might be more successful in obtaining cooperation of women if a convenient measure of volume could be devised. Since the proportionate loss in volume is greater than that in weight, the more evident result would be a motivating factor in continued effort. Also, women are more interested in size than in weight of body mass.

Second, those professions which advise exercises for reduction of size of specific body areas, have as yet no conclusive evidence that these exercises are effective. If, as this study suggests, reduction of caloric intake reduces volume to the greatest degree where fat deposits are largest, there is need for studies which will determine the amount of volume reduction which can be attributed to localized exercises.

SUMMARY

This exploratory study of loss in body volume of 10 university women during 6 weeks of a reducing diet indicates the following tentative conclusions.

1. The percentage loss in volume is approximately twice that of percentage loss in weight.
2. While there is an overall loss in volume,
   a. the area of greatest loss differs among the individuals,
   b. and each individual tends to lose proportionately more in the area where fat deposits are largest.
3. After dieting, body proportions tend to show
   a. a decrease in individual differences in lower extremities and in shoulders and upper extremities.
   b. an increase in individual differences in the trunk.

DOMINANCE OF EYE AND HAND

BY DAVID J. MERRELL

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A fascinating array of superstitions and facts has grown up around man's tendency to have a preferred hand. In most cases the superstitions are even more interesting than the facts, although it is not always possible to separate one from the other. Since the great majority of people in all groups studied are right-handed, left-handed people have long been regarded as in some way peculiar or eccentric, or clumsy, or as evil or of bad omen (*e. g.*, compare the derivations of gawky and dextrous, sinister and righteous). These beliefs are not only reflected in language, but play a part in many religious, cultural, and social practices as well. Furthermore, left-handedness has been reported to be unusually common among mental defectives, epileptics, psychotics, "degenerates," draft rejectees, and children with emotional disturbances, behavior problems, and speaking, writing, reading, or spelling difficulties (see Wile, '34 for further discussion).

Dominant handedness has been ascribed to a variety of causes, both hereditary and environmental. One of the most interesting theories, because it represents Darwinian selection in its simplest form, is the primitive warfare theory. The preference for the right hand is presumed to have arisen because the left hand was needed to hold a shield over the heart while the right wielded a spear or sword. Those who held the shield in the right hand were more likely to suffer fatal wounds in the heart, and hence the left-handed in the course of a few thousand years of primitive warfare were reduced in frequency by natural selection (Pye-Smith, 1871; Thomas Carlyle in Froude 1884; Gould, '08; Woodruff, '09). Even more widespread and more generally accepted has been the theory that the dominant hand is determined by the dominant eye (Callan, 1881; Le Conte, 1881; Gould, '08; Parson, '24; McAndrews, '35; Fink, '38; Wile, '42; Berner and Berner, '53), although opinion and some evidence to the contrary has also been presented (Stevens, '09; Kuroda, '27; Woo and Pearson, '27; Miles, '30; Krimsky, '48; Walls, '51). In connection with this theory, the difficulties in speech, writing, etc., have been attributed to mixed dominance of eye and hand, and treatments have been based on this concept (Wile, '42; Berner and Berner, '53).[1] Some of the difficulties in assessing and comparing the results of previous studies arise because of a lack of information about the criteria used to establish preference or because different criteria have been used in different studies.

THE RELATIONSHIP BETWEEN VISUAL ACUITY AND OCULAR DOMINANCE

Sir Francis Galton was one of the first to make a scientific study of lateral dominance of hand and eye in man. He collected a considerable amount of data at the Health Exhibition of 1884, which were then stored at the Galton Laboratory until analyzed much later by Woo and Pearson ('27). His criterion of handedness was the strength of grip by the right and left hands as measured by a dynamometer. The stronger hand was considered to indicate the hand preferred for acts requiring only one hand. The criterion of ocular dominance was visual acuity, which was measured in terms of the ability to read diamond type. As Woo and Pearson recognized, strength of grip may not necessarily indicate the hand preferred for tasks requiring dexterity or manipulative skill, nor may the dominant or master eye necessarily have the greater acuity. A variety of tests for ocular dominance has been used, but the essential phenomenon is one of binocular vision (Walls, '51). Under certain circumstances, even though both eyes remain open, only one can be used effectively, as, for example, in lining up a vertical pencil with a distant tree. There then occurs a suppression of vision in one eye, described by Krimsky ('48) as a "suspension of critical foveal vision in the non-dominant eye, while the dominant eye assumes the role of fixation." Woo and Pearson proceeded with their analysis upon the assumption that visual acuity and strength of grip were valid criteria of the dominant eye and hand, and reported that they could find no correlation whatever between ocular and manual dominance. Although they felt that visual acuity was actually a better measure of ocular dominance than the various sighting tests commonly used, it is clear from their data that they obtained quite different results from other workers. They found 22.82% "ocular dextralists," 54.79% "ocular ambilateralists," and 22.39% "ocular sinistralists," whereas McAndrews ('35), summarizing the results of several others using sighting tests, reported 75% right eyed, 23% left eyed, and 2% indifferent or mixed, and Miles ('30) reported for the same types 64%, 34%, and 2% respectively. Mills ('25) had noted that the dominant eye sometimes had the poorer vision, and Gahagan ('33), in a study of 100 emmetropic university students, found that there was no relationship between visual dominance and acuity, a result borne out for a completely unselected group in the present study.

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[1] The Berners distinguish between the dominant eye and the "controlling eye." However, they fail to tell how the dominant eye was determined, and their "controlling eye" appears to be what others regard as the dominant eye.

Two tests were used to determine the master eye in the work to be reported. One is similiar to the "finger pointing" test of Callan and Le Conte. As conducted here, a finger or a pencil held vertically is lined up, with both eyes open, with a vertical structure such as a tree trunk or the edge of a window or door. When the eyes are closed alternately, it is found that the pencil and the tree are no longer lined up when the dominant eye is closed. The other test, used in the questionnaire, involved puncturing a hole the size of a pencil in a large sheet of paper, which is then held at half an arm's length by the subject. In the other hand, a pencil held vertically at full arm's length is lined up by the subject with both eyes open, so that it is visible through the hole. When the dominant eye is closed, the pencil cannot be seen. Individuals wearing glasses were not requested to remove them, and hence the tests were made with corrected vision. Tests used by others (see Fink, '38 and Walls, '51 for further discussion) include looking through a cylinder at a distant object, Parson's "manuscope," a convergence test (as the object approaches the face until both eyes can no longer focus on it simultaneously, the non-dominant eye drifts away first), and sighting at a reasonably distant object through a small hole in a card held with both hands. The purpose of this last test is to cancel out the effect of handedness on the determination of the dominant eye, a possible defect in the two methods utilized for this report, but, as we shall see, a precaution which is apparently unnecessary. Generally the dominant eye was determined very quickly, but in a few cases difficulties were encountered because the subject could sight with either eye. Among those tested personally, it was possible, by the use of different variations of the test, to determine a preferred eye in all but one case. However, it was obvious that there is some variation in the strength of dominance among different individuals. In the pedigrees received there were 4 individuals (0.8%) who listed both eyes as dominant, and they were therefore omitted from the data.

The individuals in the present study were requested, if one of their eyes was "weaker" than the other, to make note of it on the questionnaire, specifying the weaker eye. While "weaker" may be an ophthalmologically unsophisticated term, it was intelligible, and the dominant eye of those specifying a "weaker" eye is shown in table 1. Possibly tests with uncorrected vision might have modified these results, but it seems unlikely because, among those tested personally with corrected and then uncorrected vision, the dominant eye remained the same. Hence, it must be concluded from the difference in frequency between Woo and Pearson's data and those of other workers (*e.g.*, Miles, '30), from Gahagan's results, and from the data in table 1 that there is no relationship between visual acuity and ocular dominance. Walls ('51) postulated that sighting dominance is not a sensory or perceptual phenomenon at all, but rather a motor ocular dominance related to the patterns of innervation sent to the rotatory muscles of one eye only, a theory which seems reasonable in the light of the above results on visual acuity.

TABLE 1

Relationship between the "weaker" eye and the dominant eye

	Dominant eye	"Weaker" eye	n
	R	R	19
	R	L	13
	L	R	15
	L	L	6
			53
$\chi^2 = 0.17$		$p > 0.95$	

CRITERIA FOR THE DOMINANT HAND

A number of criteria of handedness have been used. Most of these tests determine the hand preferred for some one-handed manipulation such as throwing, writing, bowling, or sewing, rather than strength. Though there are apparently no data correlating strength with dexterity, the frequencies of Woo and Pearson for strength of grip (64.37% "manual dextralists," 6.73% "manual ambilateralists," 28.90% "manual sinistralists") are similar to the frequencies obtained by manipulative tests, though with a somewhat higher percentage of left-handedness. Rife ('40, '50) used 10 criteria of handedness, and classified those using the left hand for one or more of the operations as left-handed, "on the assumption that ordinary environment favors right-handers." In the present study, 4 criteria of handedness were used—throwing, writing, striking a match, and threading a needle—while kicking served as the criterion for the preferred foot. When the various criteria were grouped, the convention adopted by Rife was followed. Furthermore, for similar reasons ambidexterity on a test was taken as indicative of left-handedness (Hurst, '12). This arbitrary decision had little effect on the analysis, for only 8 out of the 497 people in the pedigrees indicated use of either hand for one or more of the tests.

Needle threading was thought to be a useful addition to the tests of handedness used by others because, although generally not taught, it requires a high degree of manual skill, and is performed so seldom by most men that for them it should be relatively free of environmental influence. The hand guiding the thread was regarded as the preferred hand. It should be noted that very few of the persons tested knew which hand they used to thread a needle or which eye was their dominant eye, or even that they had a dominant eye.

RESULTS

Table 2 gives the frequency of the 6 traits studied. One hundred twenty-three persons were tested by the author personally so that the frequencies in this random unrelated group could be compared with the family groups obtained through correspondence. The excess of males is due to the greater number of male university students in the tested group and serving as propositi for the pedigrees. There are no significant differences between males and females or between the tested group and the family groups for any of these traits.

Table 3 shows the relationship among the various tests of handedness and kicking. The extremely large and highly significant chi-square values for all tests indicate that threading, throwing, writing,

TABLE 2

Per cent with left side dominant for the 6 traits analyzed

TRAIT		n	DOMINANT EYE %L	NEEDLE THREADING %L	THROWING %L	STRIKING MATCH %L	WRITING %L	KICKING %L
Tested[a]	♂	72	27.8	19.4	6.9	4.2	4.2	5.6
	♀	51	41.2	19.6	7.8	3.9	3.9	13.7
	T	123	33.3	19.5	7.3	4.1	4.1	8.9
Pedigrees	♂	261	31.8	14.6	9.2	8.0	6.9	7.7
	♀	236	30.9	19.9	7.2	8.5	6.4	6.4
	T	497	31.4	17.1	8.2	8.2	6.6	7.0
Total[b]	♂	313	30.7	14.7	8.6	7.7	6.7	7.3
	♀	264	31.1	19.7	6.4	7.6	5.7	6.8
	T	577	30.8	17.0	7.6	7.6	6.2	7.1

[a] Tested by the author.

[b] Less than the sum of tested and pedigree groups because 43 persons were common to both groups.

TABLE 3

Relationship between various traits

COMBINATION	THREADING-THROWING	THROWING-KICKING	KICKING-STRIKING MATCH	STRIKING MATCH-WRITING	HAND (ALL CRITERIA)-KICKING	HAND (OMITTING THREADING) KICKING	THREADING-HAND (OTHER CRITERIA) & KICKING
RR	403	450	447	453	399	444	399
RL	9	6	15	3	3	3	13
LR	53	11	9	12	63	18	45
LL	32	30	26	29	32	32	40
χ^2	112.42**	275.61**	215.89**	311.55**	127.12**	277.28**	137.97**

** $p < .01$

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and striking a match are related to each other and to kicking, and that there is a fundamental preference for using the arm and leg on one side of the body for most tasks. The considerably higher frequency of left-handedness for threading as compared to the other traits and to most other studies (see Wile, '34, for summary) would seem to indicate that this trait is relatively free of environmental pressure to conform. However, the low frequency of left-handed writers undoubtedly reflects environmental pressures to some extent.

TABLE 4

Relationship between dominant eye and hand

COMBINATION	EYE-THREADING	EYE-THROWING	EYE-KICKING	EYE-STRIKING MATCH	EYE-WRITING	EYE-HAND (ALL CRITERIA) & FOOT
RR	292	321	322	320	327	281
RL	48	19	18	20	13	59
LR	119	135	140	137	137	115
LL	38	22	17	20	20	42
χ^2	7.61	9.96*	5.23	7.23	13.71**	6.08

* $p < .05$
** $p < .01$

TABLE 5

Dominant eye in persons completely left-handed or right-handed (by 5 tests)

HAND	EYE	n	n [a]
R	R	281	287
	L	115	118
L	R	6	9
	L	11	11
χ^2		9.90*	5.91

[a] Four additional pedigrees received after the analysis had been completed are included here because the additional information is sufficient to shift the χ^2 from the indeterminate range to a non-significant value.

* $p < .05$

The relationship between dominant eye and handedness is shown in tables 4 and 5. Though significant chi-square values occur, there appears to be essentially no relationship between the dominant eye and the dominant hand.

Tables 6, 7, and 8 show the type of offspring resulting from different types of mating with respect to handedness. One hundred and three sets of parents and their children are included. These results confirm the influence of heredity on handedness (Jordan, '11, '14; Hurst, '12; Ramaley, '13; Chamberlain, '28; Rife, '40). All agree in finding a higher incidence of left-handedness when at least one of the parents is

TABLE 6

Handedness (all criteria—threading, throwing, striking match, writing, and kicking) among offspring from different types of matings

TYPE OF MATING	SIBSHIPS	SONS		DAUGHTERS		TOTAL	
		n	% L	*n*	% L	*n*	% L
R × R	75	97	16.5	77	23.4	174	19.5
R × L & L × L	28	32	28.2	31	41.9	63	34.9
R × L	24	28	28.6	25	48.0	53	37.7
R ♀ × L ♂	9	10	40.0	8	62.5	18	50.0
L ♀ × R ♂	15	18	22.2	17	41.2	35	31.4
L × L	4	4	25.0	6	16.7	10	20.0
TOTAL	103	129		108		237	

TABLE 7

Needle-threading incidence among offspring from different types of matings

TYPE OF MATING	SIBSHIPS	SONS		DAUGHTERS		TOTAL	
		n	% L	*n*	% L	*n*	% L
R × R	79	103	17.5	82	19.5	185	18.4
R × L & L × L	24	26	23.1	26	42.3	52	32.7
R × L	21	24	20.8	22	45.5	46	32.6
R ♀ × L ♂	7	8	25.0	6	50.0	14	35.7
L ♀ × R ♂	14	16	18.8	16	43.7	32	31.2
L × L	3	2	50.0	4	25.0	6	33.3
TOTAL	103	129		108		237	

left-handed. The demonstration of some correlations between functional handedness and dermatoglyphic patterns, which were established by the end of the fifth month of fetal development (Cromwell and Rife, '42) suggest the existence of an anatomical basis for handedness. Rife ('43) also found associations characteristic of autosomal linkage between handedness and certain dermatoglyphic patterns.

TABLE 8

Handedness (all criteria except threading) among offspring from different types of mating

TYPE OF MATING	SIBSHIPS	SONS		DAUGHTERS		TOTAL	
		n	% L	n	% L	n	% L
R × R	92	115	11.3	94	13.8	209	12.4
R × L & L × L	11	14	28.6	14	28.6	28	28.6
R × L	10	12	33.3	12	33.3	24	33.3
R♀ × L♂	6	8	37.5	6	50.0	14	42.8
L♀ × R♂	4	4	25.0	6	16.7	10	20.0
L × L	1	2	0.0	2	0.0	4	0.0
TOTAL	103	129		108		237	

The data from twins are of particular interest because in identical twins with the same genotype one may be right-handed and the other left-handed (Rife, '40). Furthermore, the intrapair variation in fraternal twins is the same as that in identical twins (Wilson and Jones, '32; Rife, '40), and left-handedness in the twin population, including both types of twins, is more frequent than in the single-born population. The distribution of handedness in both fraternal and identical twins is not significantly different from what would be expected on a random basis; that is, with $a = f(R)$, the frequency of right-handedness, and $B = f(L)$, the frequency of left-handedness, the distribution equals $a^2(R\text{-}R) + 2ab(R\text{-}L) + b^2(L\text{-}L)$ (see table 9). Thus, the information from twins alone might suggest that prenatal environmental influences are solely responsible for handedness. However, Rife ('40, '50) has shown that R-L pairs of twins of both types have a higher frequency of L sibs and parents than R-R pairs, and, of course, prenatal environmental does not explain satisfactorily the greater frequency of right-handedness in the population.

Some of the earlier authors (*e. g.*, Jordan, '11, '14, and Ramaley, '13) postulated that left-handedness was inherited as a simple Mendelian recessive trait, an idea which has persisted in the literature (Wile, '42; Gillin, '48). However, the situation clearly is not so simple, for the R-L discordance in identical twins and the production of right-handed children from L × L parents suffice to disprove it. Rife, after suggesting ('40) that handedness was a quantitative trait which could not be explained on a single gene pair basis, returned ('50, '51) to a single gene mechanism with the heterozygotes, however, quite labile so that they may become right-handed, or ambidextrous, or left-handed, but with the homozygotes fixed as to the dominant hand. With the further assumptions that where both twins, fraternal or identical, are heterozygous, one will be right-handed and the other left-handed, and in dizygotic twins with only one heterozygous, that one will be left-handed in half of the cases and right-handed in the other half, Rife showed that this hypothesis fits his twin data (table 9). The greater frequency of left-handedness among twins was attributed to the fact that half of the heterozygous twins are phenotypically left-handed, whereas a majority of single-born heterozygotes become phenotypic right-handers. All facts considered, this theory is more satisfactory than a random distribution of handedness in twins. However, the rather specialized assumptions somewhat vitiate the argument, since the handedness of the labile heterozygous twin is assumed to be firmly fixed prenatally and not further influenced by post-natal events, while the

TABLE 9

Comparison of Rife's data on handedness in twins (1950) with values expected under Rife's theory and with a random distribution

	MONOZYGOTIC				DIZYGOTIC			
	n	% 0	% *E* (RANDOM)	% *E* (RIFE'S THEORY)	*n*	% 0	% *E* (RANDOM)	% *E* (RIFE'S THEORY)
R-R	261	76.1	76.0	77.4	164	77.8	78.2	77.1
R-L	76	22.2	22.4	21.2	45	21.3	20.5	21.7
L-L	6	1.7	1.6	1.4	2	0.9	1.3	1.2

Monozygotic:

f(R) = 87.2%
f(L) = 12.8%

Dizygotic:

f(R) = 88.4%
f(L) = 11.6%

single-born heterozygote has handedness determined post-natally. However, it can also be shown that this hypothesis fits the data for the single-born reasonably well (tables 10 and 11), a further argument in its favor. The fit is not exact ($\chi^2 = 19.43$ with 5 d. f. and $p < .01$ for Rife's 1940 data on 2,178 children), but this result is not surprising in view of the arbitrary assumptions. The greatest deviation appears in the R × L matings were the % L is lower than expected. However, this deviation is in accord with Rife's suggestion that a

TABLE 10

Gene frequency analysis of handedness in single born children

MATING	POSSIBLE GENOTYPES	FREQUENCY OF MATING	FREQUENCY OF HANDEDNESS IN CHILDREN	
			R	L
R × R	RR × RR	p^4	p^4	
	RR × Rr	$2p^3q$	$\frac{3p^3q}{2}$	$\frac{p^3q}{2}$
	Rr × Rr	p^2q^2	$\frac{p^2q^2}{2}$	$\frac{p^2q^2}{2}$
TOTAL			$\frac{p^2}{2}(p+1)$	$\frac{p^2q}{2}$
R × L	RR × Rr	$2p^3q$	$\frac{3p^3q}{2}$	$\frac{p^3q}{2}$
	RR × rr	$2p^2q^2$	p^2q^2	p^2q^2
	Rr × Rr	$2p^2q^2$	p^2q^2	p^2q^2
	Rr × rr	$2pq^3$	$\frac{pq^3}{2}$	$\frac{3pq^3}{2}$
TOTAL			$\frac{pq}{2}(2p+1)$	$\frac{pq}{2}(2q+1)$
L × L	Rr × Rr	p^2q^2	$\frac{p^2q^2}{2}$	$\frac{p^2q^2}{2}$
	Rr × rr	$2pq^3$	$\frac{pq^3}{2}$	$\frac{3pq^3}{2}$
	rr × rr	q^4		q^4
TOTAL			$\frac{pq^2}{2}$	$\frac{q^2}{2}(q+1)$

R = gene for right-handedness
left-handedness

p = frequency of R
q = frequency of r

majority of the single-born heterozygotes, rather than the 50% assumed here, become right-handed. It is clear that neither hereditary nor environmental factors alone suffice to account for the genesis of handedness. The discordance between identical twins proves the importance of environmental factors while the discordance between a left-handed child and his completely right-handed cultural and familial environment indicates the importance of innate factors in the development of handedness. Hence, the statement of Sir George Humphry in 1861 may still adequately state the situation: "I am driven, therefore, to the rather nice distinction, that, though the superiority [of the right hand] is acquired, the tendency to acquire the superiority is natural [i. e., hereditary]."

TABLE 11

Frequency of left-handedness in offspring from various types of matings

MATING	EXPECTED [a] (RIFE'S THEORY) % L	OBSERVED RIFE ('40) % L
R × R	6.0	7.6
R × L	31.0	24.3
L × L	56.0	54.5

[a] Assuming 50% of Rr are right-handed and 50% are left-handed and f(L) = 12.0% (the frequency assumed by Rife in his 1950 paper on twins).

Lauterbach ('25) and Chamberlain ('28) reported a greater frequency of left-handed males than females, but Jordan ('14) found no significant differences. There are no significant differences between males and females in the present study for any of the traits shown (table 2). The apparent excess of left-handed women in table 6 is due to the somewhat greater, but not significant (table 2) frequency of women who thread a needle left-handed (tables 7 and 8).

The influence of heredity on the dominant eye is shown in table 12, from which it is clear that the frequency of dominance in the left eye is considerably higher when one or both of the parents also has the left eye dominant. Although various authors have referred to the dominant eye as an inborn or hereditary trait, often in relation to discussions of handedness, apparently no pedigrees have previously been published. The exact genetic mechanism must await further study, but it is clear that a straightforward single gene hypothesis is not adequate to explain the results. Since ocular dominance is only established by about the age of three (Fink, '38), it is probable that both prenatal and postnatal environmental factors also play some role in its determination.

TABLE 12

Dominant eye among offspring from different types of matings

TYPE OF MATING	SIBSHIPS	SONS		DAUGHTERS		TOTAL	
		n	% L	*n*	% L	*n*	% L
R × R	56	75	22.7	56	25.0	131	23.7
R × L & L × L	47	54	46.3	52	46.2	106	46.2
R × L	36	42	40.5	40	47.5	82	43.9
R ♀ × L ♂	21	28	32.1	25	56.0	53	43.4
L ♀ × R ♂	15	14	57.1	15	33.3	29	44.8
L × L	11	12	66.7	12	41.7	24	54.2
TOTAL	103	129		108		237	

DISCUSSION

In view of the number of harmful conditions supposedly related to or attributable to left-handedness, to changed dominance, or to mixed dominance of eye and hand, it would seem desirable to investigate most carefully, with adequate controls, the actual relationships involved. Since many of the previous studies were undertaken with erroneous assumptions, particularly as to the relationship between ocular and manual dominance, new insight into such difficulties as stuttering and reading problems may be forthcoming.

Furthermore, while it is clear that heredity plays a role in the development of dominance of both eye and of hand, the mode of operation of these genes in the developing individual is not known, nor is it understood how dominance can be modified by environmental conditions.

The demonstration of the influence of heredity on the dominant eye adds still another to the list of inherited traits in man. Although it appears that a simple one-gene hypothesis will not adequately explain the data, further information from more extensive pedigrees and from twins may make possible the framing of a relatively simple genetic hypothesis. If so, this trait may then become very useful in the study of human genetics, for ocular dominance is easily determined, and both types of dominance are so frequent that segregation will commonly occur within families under study.

SUMMARY

1. Ocular dominance is shown to be unrelated to visual acuity, and hence is probably a motor phenomenon rather than a sensory or perceptual phenomenon.
2. A close relationship exists among four tests of hand preference and one for the preferred foot.
3. There is essentially no relationship between ocular dominance and the dominant hand.
4. A higher incidence of left-handedness is found when one or both parents are left-handed, in agreement with previous studies. The modified single-gene hypothesis applied by Rife ('50) to twins is shown to apply also to the single-born.
5. In matings R × R for dominant eye, 23.7% of the children had the left eye dominant; in R × L, 43.9%; and in L × L, 54.2%, thus demonstrating the influence of heredity on this trait.

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a. Are the assumptions to be used based on sound ecological and physiological data for animals?

b. Are the conclusions derived in accord with the facts of human physiology?

c. Are the specified ecological forces which influence animals really affecting man in an identical manner?

The facts force me to say, "no," to each of the above questions when they refer to man and the postulates or so-called "rules" of Bergmann and Allen. A demonstration of the invalidity of these concepts in human ecology is the theme of this paper.

Do these rules apply to animals? Many examples are cited in the ecological literature to support the views of Bergmann and Allen. Rabbits are said to have leaner and longer ears as we progress southward from the polar regions; however, different species of rabbits are involved. The barren ground caribou is given as larger than the more southern forest species. The extensive migrations back and forth of these animals should not be ignored and the greater severity of cold in the subarctic forests is a pertinent factor. The penguins of the extreme south are said to be larger than those nearer the equator. But, large and small penguins are found together in some antarctic areas. In all these examples when one examines the basic data, the differences in size and weight are relatively trivial and do not in any clear manner give evidence of overwhelming cold survival value to the heavier forms (Scholander, '55).

Of basic importance to the acceptability of these "rules" is the assumption that in animals heat production is a function of mass and heat dissipation a simple function of surface area. The tenuous nature of the latter assumption is clear from a careful examination of temperature regulating mechanisms in mammals.

I propose to refer to that school of thought which explains the origin of human racial types in terms of Allen's and Bergmann's postulates as "climatic determinists." It is my contention that their stand is based on inadequate data improperly interpreted. As I view human ecology, one constant factor repeats itself: Man, from his earliest origins, has not responded to his environment in a willy-nilly fashion but has rather done everything possible to control and shape that environment to conform to his ideas of comfort and convenience.

The climatic determinists ordinarily suggest that adipose tissue in animals serves as a dead, insulating blanket which inhibits effective heat exchange between the animal and its environment. Witness the so-called rule of Rensch which attempts to explain fat distribution in certain species on the basis of heat transfer "needs" of the animal. These generalizations show great inventiveness and may have a germ of truth but unfortunately are not completely in accord with physiological fact. Adipose tissue is not a dead, inactive thing, but is quite active metabolically (Schoenheimer, '46). For metabolic purposes the capillary bed of fat tissue is comparatively richer than that of muscle (Wertheimer and Shapiro, '48). The blood vessels are innervated by sympathetic nerve fibers. One wonders, then, what stimulus is adequate to induce the deposition of fat over all the body of cold-dwelling mammals and only in the tail or buttocks of certain dwellers in warm areas. From the physiological point of view climate does not impress one as adequate.

One is told that the seals of the Arctic Ocean have a layer of insulating blubber; but, the seals and sea lions from the warm waters of California are not particularly skinny; nor is the Florida manatee a striking example of spare build.

In the cold, homeotherms adjust for survival by increasing metabolic rate, by increasing insulation, by selecting a favorable microclimate, and by maintaining cold extremities to reduce heat loss from the core (Scholander, '55). For example, the Eskimo husky dog and the Arctic fox have a critical temperature of at least —40° C. The critical temperature, as you know, is the lowest air temperature at which an animal can maintain a resting or basal metabolic rate. This ability to remain in a resting metabolic state at very low temperatures is a result of increased insulating capacity of the fur which in these species is fluffed up in the cold. The typically Arctic lemming has a critical temperature around +10° C., but this species and others like it select suitable microclimates near freezing, and many build warm nests. In these cases behavior patterns and not morphological ones make for survival in cold. Caribou and sea gulls conserve body heat by maintaining cold extremities. The caribou on cold days keeps its thin legs at +10° C., or lower. Arctic gulls have been kept with their feet in ice water for several hours and the basal metabolic rate goes up only about 1.5% (Scholander *et al.*, '50). The gull preserves body heat by holding the tissue temperature of the legs near zero. Moreover, cellular adaptations occur which permit portions of nerve axons in these cold parts to conduct effectively at depressed temperatures (Chatfield *et al.*, '53).

Some arctic and subarctic dwellers meet the enormous heat losses by increasing metabolic rate for prolonged periods. The red squirrel of Central Alaska does just that, and it is not a particularly globular type of homeotherm but it seems well established in its northern neighborhood.

There is no clear-cut physiological evidence that homeotherms tend to a globular form with reduced extremities in the face of cold exposure. There is a wealth of evidence that adapted homeotherms in the cold decrease heat loss by increasing insulation and by maintaining cold extremities; some turn up the thermostat, as it were, and increase heat production. On the basis of our present knowledge the rules of Bergmann and Allen appear to be of historical or descriptive interest only and certainly are not valid generalizations for animals in the cold.

In the heat, the views of the climatic determinists are also open to question. For example, "Neither the ratio of surface area to body weight, nor the ratio of surface area to the two-thirds power of body weight, showed a significant difference between Jersey cattle and Sindhi-Jersey crosses, although the latter have appreciably greater heat resistance than do the former" (McDowell *et al.*, '53). In other words, heat tolerance could not be attributed to greater proportional surface, large dewlap or other morphological peculiarities.

Need one mention that the hippopotamus, rhinoceros, and elephant are built on the roly-poly, globular pattern, but are well entrenched in their tropical environments? The camel is adapted to its normal hot environment; not by reason of its morphology but because its tissues can withstand elevated temperatures for long periods. In order to conserve water, evaporative cooling is depressed to a minimum during water shortage in the camel; the rectal temperature may rise from 34.2 to 40.7° C. during the day with no harm to the beast (Kleiber, '56). It would seem that readjustment of cellular mechanisms and not alteration of body form is the key factor in animal adaptations to heat. Birds which live in the desert adapt in a similar fashion and many avian species respond to heat by reduced metabolic heat production (Gelineo, '55).

Mayr ('56) re-emphasizes the fact that the so-called rules of Bergmann and Allen are "purely empirical generalizations describing parallelisms between morphological variation and physiogeographic features." He admits that too many writers have elevated these purely descriptive comments to the status of laws. In reality these rules have "only statistical validity." It is good to know that competent zoologists appreciate this fact. However, the point at issue remains: Some anthropologists and sociologists are using these descriptive generalizations to explain human racial variations as if they were laws having causal value. Such usage is misleading and unjustified.

Do these rules apply to man? If the contentions of the climatic determinists are valid, one must visualize the historical Eskimo as a wretched creature with teeth and bones rattling from cold. Then in a good Lamarckian fashion he should have shortened his legs and arms and inflated his body to resemble "Mr. Five by Five." In this way he would produce much heat and lose little of it and thus be adapted to the severe Arctic. This globular form would be transmitted to his children and his children's children. Unfortuately for this view, the Eskimo never read about Bergmann's or Allen's rule; so they cheated. Instead of shivering they manufactured the warmest type of clothing known to man and devised homes which maintained rooms at tropical temperatures. On the trail their bodies, with exception to face and sometimes hands, were at temperatures of 80–90° F. At home they lived in sod or snow shelters with interior temperatures up to 100° F., so hot in fact that these people usually rested stripped to the waist (Stefansson, '21). Under such conditions the stimulus of climate is a tropical one which should have made them tall and skinny. In the face of a tropical microclimate (which is of course the real stimulus acting on the Eskimo) this race is held, by the climatic determinists, to develop morphological adaptations of positive survival value in the cold.

Jenness ('23) has pointed out that, with respect to all Eskimos, "The fur clothing in which they are habitually enveloped gives them an exaggerated appearance of corpulence, whereas in reality they incline towards slenderness, the body tapering a little below the broad shoulders."

The Eskimos living at Point Barrow during the last century showed no evidence of spherical build. The following data illustrate this fact:

	Males	*Females*
Average weight, lbs.	153.5	135.7
Average height	5′ 3″	4′ 11″

These results are from Ray's (1885) report of his expedition to Point Barrow between 1881 and 1883.

The only real cold people in the world were the aborigines of Tierra del Fuego and of Australia. The former were never studied from the metabolic point of view. However, Darwin and others have described them as thin, small people who lived, worked and rested stark naked even in severe snow storms. The Australian aborigines in their native state are able to rest naked at 0° C. while maintaining a basal heat production (Hicks *et al.*, '34). They are a small, skinny people whose build, according to climatic determinists, should have evolved in response to heat, whereas they show remarkable physiological adaptation to cold. If any groups of men should show a globular form with relatively short extremities, it is the Australian aborigine and the Tierra del Fuegians. The fact that they show opposite of the expected response to the climatic determinist rules illustrates the danger of explaining human racial morphology in terms of Bergman's and Allen's generalizations.

We are quite ignorant of the physiological adaptations to cold in the Fuegians. The Australian aborigine, on the other hand, has been studied metabolically. He shows physiological adaptations characteristic of Arctic animals: Extremely active control of cutaneous circulation which results in maintenance of cold skin and extremities in decreased environmental temperatures with consequent saving of heat (Wulsin, '49). These adaptations are functional and do not involve changes in exterior body form. They are the only clear-cut biological adaptations of man to cold that we know.

Bates ('53) contends that, "It is easy to assume that, since the races show a pattern of geographical distribution, they represent adaptation to different geographical environments; and, with a certain amount of ingenuity, all sorts of adaptive traits can be described." However, under careful study these schemes usually disintegrate. As a rule, diagnostic, structural peculiarities of human groups show no evidence of being adaptive; they may be correlated with differences in function or behavior and these latter are certainly adaptive. The solution of this problem lies in the experimental approach to racial matters and not in the use of descriptive generalizations as though they were causal agents in the formation of races.

Man a tropical mammal: Man in all his adaptations is ordinarily a tropical mammal. (The responses of the Australian native to cold are an exception). He responds to cold by keeping his extremities warm (contrary to adaptation in true Arctic homeotherms which maintain cold extremities and thus conserve heat), a process wasteful of heat and characteristic of a tropical animal. He adapts to heat by measureable physiological adjustments: Increased volume of sweat, greater dilution of sweat, hemodilution, decrease in heart rate during activity. These adjustments make it possible for man to live and work effectively in hot climates without the aid of artifacts. There are few proven physiological adaptations of man to the cold. In the face of low ambient temperatures, man either adds clothing, heats his dwelling, or combines the two. Naked, he is usually helpless in the cold; naked, he adapts to the heat in an effective manner.

Newman ('56) has outlined the physiological adjustment that man makes to cold. It is true that the Eskimo is better able to live in the cold than is the Negro. But the Eskimo handles the problem by a typical tropical response: the maintenance of warm extremities. This in turn requires high caloric intake and expenditure, a fact which denies the Eskimo as an example of a heat conserving mechanism operating in the cold.

SUMMARY

This brief and rapid survey does not postulate that climate is without effect on man. At another time the ecological effect of this variable on man will be discussed. This presentation attempted to show in a sketchy fashion the following:

1. The rules of Bergmann and Allen find little support *as causal agents* in modern studies of temperature regulation in homeotherms.

2. The various formal examples often cited in favor of these ecological generalizations do not support the case of the climatic determinists. One is forced to conclude that the rules just do not apply causally to animals.

3. In man the ecological forces supposed to be acting are not doing so; Eskimos were not cold, the skinny aboriginal Australians were.

4. The rules of Bergmann and Allen have no causal role in the formation of racial differences in man. Such use of these rules on the part of some anthropologists is a source of misinformation and confusion.

5. Some human groups have met the demands of severe climate by technological and behavioral adjustments; the Eskimos are an example. Others have developed specific heat-conserving functional changes, with no gross morphological changes; the Australian aborigines are an example.

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ROENTGENOGRAMMETRIC DETERMINATIONS OF BODY COMPOSITION[1]

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INTRODUCTION

THE technique of measuring the fat-plus-skin shadow on suitably light soft-tissue x-rays was introduced by H. C. Stuart in 1940 (Stuart, Hill and Shaw, '40). Since that time it has been widely used, primarily in America (Reynolds, '51), and to some extent in England (Tanner, '55) and in Spain (Suarez, '53). There are, at the time of this writing, some 50 published studies dealing with the thickness of the subcutaneous fat on various parts of the body and in both sexes. The age range of subjects so studied encompasses the entire life span, from earliest infancy through the seventh decade.

Investigations involving the fat-plus-skin shadow have varied in their purpose. Many of the earlier studies were essentially normative. More recently, the problem of configuration has come into prominence. And, the range of problems has included the stability of individual fat patterns, changes in subcutaneous fat during weight loss, the relation between fat and growth progress, the quantitative assessment of obesity, and the relationship between x-ray and pinch-caliper measurements of superficial fat.

However, it is evident that the thickness of the subcutaneous fat layer, or "outer fat" is at least roughly proportional to the total weight of fat. For one thing, weight and fat show moderate to high correlations, when the "best" fat sites are considered (*cf.* Garn, '57a, '57b). Again, the thickness of the subcutaneous fat is inversely related to specific gravity. Without endorsing the oft-stated assumption that outer and inner fat are equal—a relationship manifestly impossible in obese subjects—it is nevertheless obvious that people with thicker subcutaneous fat deposits are fatter and weigh more. This leads to the possibility of estimating the *weight* of fat from the *thickness* of selected fat sites.

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The possibility of estimating the weight-of-fat (and the fat-free weight as well) from fat thickness and gross weight was explored in a preliminary study (Garn and Harper, '55) wherein the group means appeared to be reasonable, in comparison to other published data. Further, individual estimates of the weight of fat, based on fat-thickness data, were compared to a biochemical index of obesity, and it was shown that the biochemical index not infrequently yielded palpably improbable estimates (Garn and Clark, '55). However, a critical analysis of the method and consideration of findings derived therefrom, were premature at that time.

More recently we have been able to extend these studies to a larger number of individuals (251), including both sexes and a carefully selected series of young adult males with a very narrow age range. The results obtained appear to be most encouraging both in terms of the immediate findings, and toward further applications of the method. The roentgenogrammetric method has the particular advantage of being capable of providing information not only on fat (and therefore the fat-free mass), but also of providing estimates of muscle mass and skeletal weight as well.

METHODS AND MATERIALS

The present study is based upon standardized soft-tissue x-rays of 251 adult men and women.

The first group of subjects consisted of 94 American-born white women, all mothers of children in the Fels Longitudinal Series. Most of them were occupied as "housewives" but approximately 33% were engaged in clerical, secretarial or managerial jobs away from home. The age range was 20 to 64 years, and the means for age, stature, and weight were 37.2 years, 162.3 cm, and 60.4 kg. Stature was closely comparable to the mean height of WAAF basic trainees (Daniels, Myers and Worrall, '53), the Minnesota volunteers studied by Skerlj, Brožek and Hunt ('53) and the standard statures assumed by Behnke ('53,

p. 1107). Average weight agreed closely with that of the Minnesota women, and with the 35 year old group-standard given by Behnke.

The second group of subjects included 75 adult white American-born men, all of them Fels fathers, and like the mothers, primarily of Northwest European extraction. With an age range identical to that for the women, and a very slightly higher mean age (40.3 years), the means for stature and weight were 176.3 cm and 76.0 kg. Mean stature was within 1.0 cm of the Behnke standard, and of the mean for the older Minnesota men tabulated by Brožek ('52). In average weight the men were 2 kg above the Behnke value for comparable age and close to the groups summarized by Brožek in tables 2 and 5 of his paper. About half of these Ohio male subjects were engaged in farming, skilled labor, and other tasks requiring considerable physical activity.

The third group consisted of 82 American-born white male college students, selected to provide a narrow age range of 21.0 to 22.9 years: the mean age was 21.7 years. In mean stature (178.3 cm), and weight (72.6 kg), they were above the Army medians reported by Newman ('56). Only a few of the students were regularly active in college athletics but several engaged in semi-pro sports away from college. Since approximately 35% of them were of Southern or Southeastern European ancestry, the student sample was tabulated separately from the Ohio males.

The soft-tissue x-rays were taken at a 6 foot tube-to-film distance, at 18 milliampere seconds, and at 40–80 Peak Kilovolts, depending upon part thickness. Fast film, intensifying screens and normal development were used throughout. The circle of irradiation was reduced to a minimum, through the use of a double-diaphragm cone. Even without special gonadal shielding introduced in these studies in 1955 (Garn, '57a and Garn, Sontag and Silverman, '57) gonadal radiation was far *below* 0.1 r (100 mr) (which is approximately the yearly natural background dosage (*cf.* Neher, '57). The fat-plus-skin shadows on the radiographic films were measured at right angles to the skin surface, using ground-tip vernier calipers.

Individual estimates of body fat were based on mid-trochanteric fat (T_2) for males and iliac crest fat (I_1) for females, by using constants appropriate to the group in question. These particular sites were selected as having (1) the greatest communality with other measured fat sites, and (2) highest correlations with weight (*cf.* Garn, '54; Garn and Clark, '55; Garn, '57c). Although we had intended to base fat-weight estimates on multiple fat sites, a detailed comparison of equations based on single and multiple predictions showed no great improvement in predictive efficiency when more than one site was included (Garn, '57b). Accordingly, the simpler procedure was used throughout even though data on 8 other fat sites were available.

The technique of estimating individual weight-of-fat values from the regression of weight on fat may be considered in terms of the simple prediction equation

$$y = ax + b$$

wherein weight (y) bears a nearly straightline relationship to the fat thickness (x), with a slope defined by the constant (a).

As Behnke ('53) has pointed out, weight may be considered as having two components, the fat-free weight (here equivalent to b) and the weight of fat (here equivalent to ax).

Hence, if b is subtracted from both sides of the equation,

$$y' = ax$$

and ax equals the weight of fat.

Now the constant a is easily determined from the values of r, σy and σx since

$$a = r \frac{\sigma y}{\sigma x} x$$

as described in Peters and Van Voorhis ('40).

Thus, if the individual value of fat (x) is multiplied by the constant (a), an estimate for the individual's weight of fat is obtained.

And, as should be obvious, since $y - y'$ equals the fat-free weight, subtracting ax from the individual's gross weight yields an estimate of his lean or fat-free weight.[2]

The utility of this method depends upon several assumptions, one being linearity of the fat-weight relationships and another being a lack of correlation between gross size and fat. Both assumptions were shown to hold within the limits of the present data. Again, the success of this method depends upon the relative independence of the fat-free weight from the weight of fat. This was shown, not only by the correlation method, but also by replicate estimates on individuals who had gained or lost considerable fat. A further documentation of this point appears in the next section.

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[2] It will be noted that the estimated fat-free weight is, in every case, an *individual* estimate obtained by subtracting ax from gross weight, and not the group intercept b.

It is important to point out that the findings given in this paper, and in particular the constants used in the weight-of-fat estimates should not be applied to other groups without due caution. Whereas the constants necessarily fit the data, they are ultimately derived from *r* and this in turn is subject to sampling error. Finally, the technique is not applicable to individuals who have rapidly lost weight, or to others in whom the normal relationship between weight and subcutaneous fat thickness has been disturbed as during semi-starvation (Garn and Brožek, '56) or in lipo-distrophies.

FINDINGS

Estimates of the weight of fat were calculated upon an individual basis, using trochanteric fat (T_2) for the male series, and iliac crest fat (I_1) for the 94 females. The constants 0.76, 0.81 and 0.72 were employed for the student series, the Ohio male series, and the Ohio female series respectively.

As shown in table 1, all three fat distributions were markedly and positively skewed, in the manner characteristic of fat. Skewness in the two male series was effectively of the same type. However, the female fat values were even more positively skewed, and the distribution was flatter. Thus, there is very good reason to avoid the mean and the standard deviation when reporting weight-of-fat data.[3]

As might be expected, the Ohio males (who were somewhat heavier than the students) proved fatter, with a median weight of fat of 12.7 kg, as contrasted to 9.0 kg for the college males, a difference almost equal to the difference in weights. Nearly 60% of the students had 10.0 kg of fat or less, as compared with approximately 30% of the Ohio men. The women, in turn, proved fatter than either male group, though only slightly more so than their husbands, and 4.5 kg more than the college males. For all three groups the lowest 5%, or truly lean individuals, possessed 6 kg of fat or less. But the "obese" category, or upper 5% included those Ohio women in excess of 30 kg of fat, the Ohio men who had 23 kg of fat or more, and the students whose weight of fat exceeded 25.5 kg (these values were obtained from the percentile distributions before grouping into class intervals as shown in table 1).

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[3] With variations in skewness, two very dissimilar distributions may have the same mean and two rather similar distributions may have different means.

Fat-free weights were calculated, again on an individual basis, by subtracting the estimated weight of fat from gross weight. Here, one would not anticipate a large difference between the two male series (barring accidents of sampling) and this expectancy was confirmed (table 2). The median fat-free weight was 58.2 kg for the Ohio males, and 62.5 kg for the taller and younger students. However, one subgroup in the Ohio series consisting of farmers (see above) had a median fat-free weight of 68.5 kg. The women, in turn, had far lower fat-free weights, with a median at 42.3 kg, approximately 66% of the median male value. Although there was a fair overlap between the women and the men in respect to the fat-free weight, only one woman actually equalled the combined male median value. This finding is consistent with other data and estimates of fat-free weights (*cf.* Behnke, '53, Edelman *et al.*, '52).

TABLE 1

Distribution of estimated fat weights

FAT WEIGHT (Kg)	94 OHIO FEMALES No.	94 OHIO FEMALES %	74 OHIO MALES No.	74 OHIO MALES %	82 COLLEGE MALES No.	82 COLLEGE MALES %
2.5– 4.9	4	4.3	4	5.4	6	7.3
5.0– 7.4	17	18.1	8	10.8	23	28.1
7.5– 9.9	15	16.0	10	13.5	19	23.2
10.0–12.4	8	8.5	14	18.9	11	13.4
12.5–14.9	8	8.5	11	14.9	6	7.3
15.0–17.4	2	2.1	9	12.2	4	4.9
17.5–19.9	8	8.5	9	12.2	4	4.9
20.0–22.4	8	8.5	4	5.4	3	3.7
22.5–24.9	6	6.4	3	4.1	1	1.2
25.0–27.4	5	5.3	1	1.4	3	3.7
27.5–29.9	6	6.4	1	1.4	—	—
30.0–32.4	5	5.3	—	—	1	1.2
32.5–34.9	1	1.1	—	—	—	—
35.0-37.4	1	1.1	—	—	1	1.2
MEAN	16.0		13.4		11.04	
MEDIAN	13.5		12.7		9.0	

It is of some interest to consider the range of fat and fat-free weights as an indication of the variability of the several body compartments. The range of fat weights was approximately 2 to 36 kg; the most obese woman was 18 times as fat as the leanest subject. On the other hand, the range of fat-free weight was 30 to 62 kg for women (a ratio of 2:1), and the comparable ratio for the males was 1.7:1. Fat variability thus appears to be extremely great, and if fat is not "the most variable tissue," certainly it is an excellent contender for that title.

TABLE 2

Distribution of fat-free weights

ESTIMATED FAT-FREE WEIGHT (Kg)	94 OHIO WOMEN 20–60		74 OHIO MEN 20–60		82 COLLEGE MEN 21–22	
	No.	%	No.	%	No.	%
28.0–31.9	2	2.1	—	—	—	—
32.0–35.9	4	4.3	—	—	—	—
36.0–39.9	16	17.0	—	—	—	—
40.0–43.9	17	18.1	—	—	—	—
44.0–47.9	32	34.0	—	—	2	2.4
48.0–51.9	14	14.9	6	8.1	3	3.7
52.0–55.9	7	7.4	5	6.8	11	13.4
56.0–59.9	1	1.1	16	21.6	20	24.4
60.0–63.9	1	1.1	20	27.0	22	26.8
64.0–67.9	—	—	9	12.2	10	12.2
68.0–71.9	—	—	8	10.8	7	8.5
72.0–75.9	—	—	5	6.8	6	7.3
76.0–79.9	—	—	5	6.8	—	—
80.0–83.9	—	—	—	—	—	—
84.0–87.9	—	—	—	—	1	1.2
MEAN	44.6		62.4		61.5	
MEDIAN	42.3		58.2		62.5	

The data here presented further testify to the greater relative fatness of the female. Though not much fatter than the males in absolute terms, expressed either in relationship to total weight or to the fat-free weight the female is proportionately fatter. Using the more common computation, fat as a percentage of gross weight, the median percentage of fat for males was 16.8% as contrasted with 23.7% for their wives: the frequency distribution shows the extent of sexual dimorphism in this respect (figure 1). However, expressing fat in relation to the fat-free weight more effectively portrays the sex difference and singles out those individuals whose weight of fat equals or exceeds their fat-free weight. As shown in figure 2, there are a few phenomenal individuals with a fat to fat-free ratio of 100 or even more!

Sorting the fat-free weights in respect to stature served to check whether the present method effectively takes stature into account. As shown in table 3, there is a progression of fat-free weights from the first to the fourth stature quartile in each group. The shortest women had a low median fat-free weight (39.9 kg), while the median fat-free weight for the fourth stature quartile was 47.9 kg. In the Ohio males a similar upward trend was evident: the median fat-free weight rose from 56.2 kg in the first stature quartile to 65.6 kg in the fourth. And

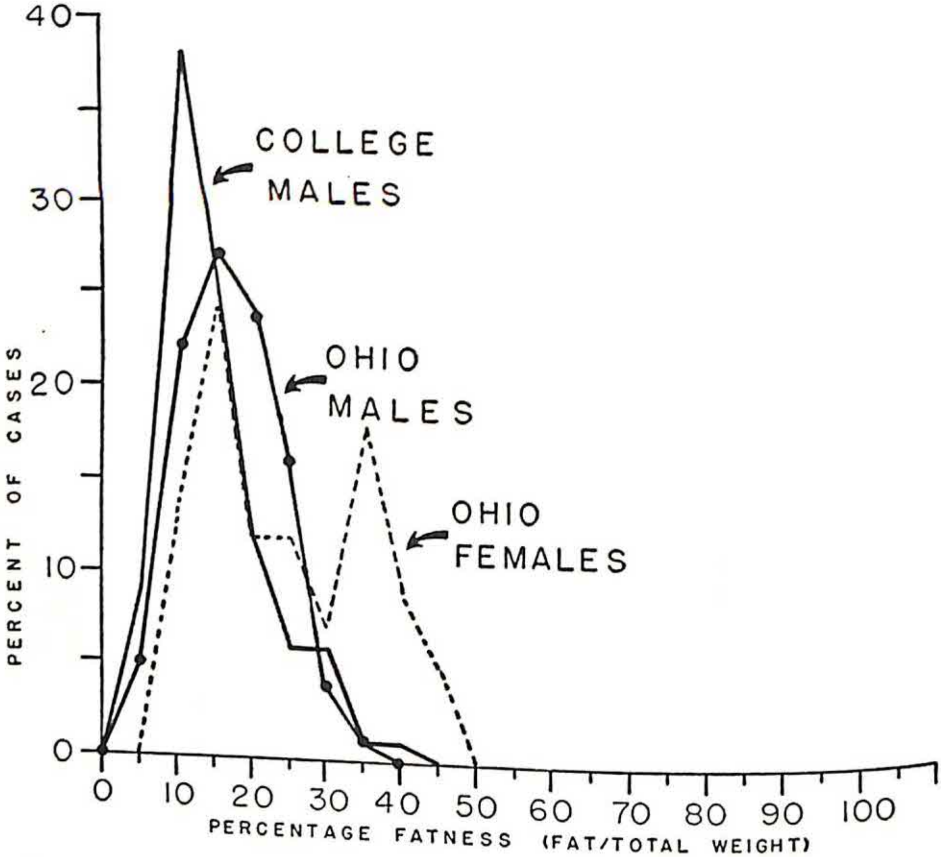

FIG. 1. FAT EXPRESSED AS A PERCENTAGE OF GROSS WEIGHT: THE TWO MALE SERIES ARE THE SAME FORM AND OF EQUAL SKEWNESS WHEREAS PERCENTAGE OF FAT IN FEMALES SHOWS SKEWNESS OF A MORE EXTREME TYPE AND BI-MODALITY.

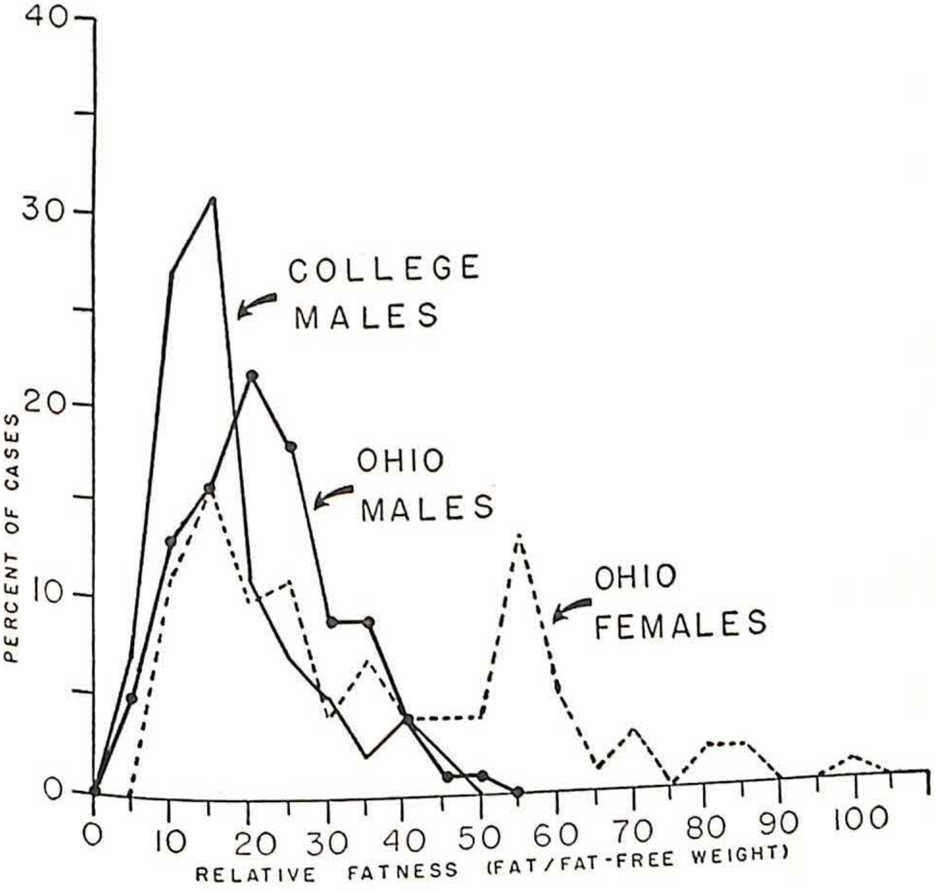

FIG. 2. FAT EXPRESSED AS A PERCENTAGE OF THE FAT-FREE WEIGHT. HERE THE SEX DIFFERENCE IS MADE MORE APPARENT AND THE EXTREMELY OBESE INDIVIDUALS IN WHOM THE WEIGHT OF FAT EQUALS OR EXCEEDS THE FAT-FREE WEIGHT ARE MORE PERFECTLY DESIGNATED (see text).

TABLE 3

Fat-free weight by stature quartiles

	OHIO WOMEN 20–60		OHIO MEN 20–60		COLLEGE MEN 21–22	
STATURE QUARTILE	STATURE (cm)	FAT-FREE WEIGHT (kg)	STATURE (cm)	FAT-FREE WEIGHT (kg)	STATURE (cm)	FAT-FREE WEIGHT (kg)
q 1	157.0	39.9	169.9	56.2	170.6	56.1
q 2	160.9	45.1	173.7	60.2	176.6	56.5
q 3	164.2	45.8	177.8	60.2	180.7	59.9
q 4	169.2	47.9	182.9	65.6	185.4	64.4

the student group almost duplicated this trend, with an increase from 56.1 kg to 64.4 kg. Since the median fat-free weight, equivalent to the value of b (the y intercept of x) is obviously different for different stature groups, the possibility of using values of a specific to each stature grouping was considered. However, while preliminary analyses showed slightly improved estimates of the fat-free weight at extremes of stature, when using stature-specific constants, the size of the present samples was too small to compute definitive stature-specific values of a.

The final problem was that of reliability of the method, primarily in respect to the estimates of fat-free weight. Granted that immediate reproducibility of results may be high (limited only by the standardization of the x-ray poses and precision of the fat measurements), how consistent are the estimates of fat-free weight when fat itself increases or decreases? The limiting assumption here is that the fat-free weight is reasonably stable within normal limits of weight variability.

TABLE 4

Replicability of fat-free weights after weight gain or weight loss

SUBJECT NO.	SEX	WEIGHT (kg)		ESTIMATED FAT-FREE WEIGHT (kg)		WEIGHT CHANGE (kg)	APPARENT DIFFERENCE (kg)
		1	2	1	2		
0277	f	79.2	68.9	37.7	35.3	—10.3	—2.4
1	f	71.4	58.6	47.1	46.1	—12.8	—1.0
27	f	58.0	59.7	47.7	47.1	1.7	—0.6
112	m	69.4	73.2	54.5	57.6	3.8	3.1
20	m	92.9	84.8	69.9	68.9	—8.1	—1.0
0371	m	78.3	72.7	67.1	66.1	—5.6	—1.0
0245	m	68.6	75.9	62.3	64.7	7.3	2.4
45	m	94.1	89.1	72.7	71.3	—5.0	—1.5
46	m	81.6	90.1	61.1	61.6	10.5	0.5
47	m	77.5	88.0	63.2	61.6	10.5	—1.5

As shown in table 4, the present technique appears to yield fat-free weight estimates reproducible within ± 2 kg, or 2-5% of gross weight. Using a series of 10 adult subjects who had gained or lost up to 12 kg, the correlation between independent estimates of fat-free weight was 0.988. Actual differences in the estimated weight of fat ranged from — 1 to + 3 kg. Thus, while it is possible that the fat-free weight did change between examinations in some of the cases (as suggested by the sign test) the apparent changes in the fat-free weight may be used as a measure of the experimental error. Interestingly, the magnitude of the experimental error, thus estimated under rather rigorous conditions, approximates the extent of error reported in replicate studies of the blood-dilution method, as described by Edelman *et al.* ('52).

What is notable here is that the findings agree well with other published studies on fat weight, the weight of the fat-free mass, and sex differences in percentage fat in American men and women of approximately "standard" height and weight.

DISCUSSION

It is evident from these findings that roentgenogrammetrically determined estimates of body composition in adults yield results that are both reasonable and agree well with many values for the weight of fat and the fat-free weight obtained by the densitometric and blood-dilution techniques.

The data for the men are of particular interest because of the number of male series available for comparison, and the good agreement that exists among them. At 176 cm and 76 kg the estimated *mean* weight of fat for the Ohio men was 13.4 kg; this is virtually the same as the mean of 13.7 kg given by Behnke ('53, p. 1095) for men of equivalent size and weight. It is, however, slightly above the estimate given by Edelman *et al.* ('52) for somewhat lighter men, and lower than Brožek's estimate for older Minnesota men of "standard weight" (Brožek, '52). Similarly the estimated mean weight of fat for the student group, 11 kg, agrees within 1 kg with Behnke's value for men of comparable weight, and while 4 kg higher than the value given by Brožek for 48 university students of comparable age (but lower weight), the net difference is not over 1 kg when weight is taken into account.

The female fat data are somewhat more difficult to compare, because published values fall both above and below our mean of 16.0 kg for Ohio women. Edelman *et al.* ('52) give a mean of 17.0 kg for females somewhat lighter than ours. Behnke, on the other hand, provides an estimate of 11.5 kg for women almost identical to ours in the stature and weight. Here, the rather large discrepancies may be due to true differences between the samples, a point emphasizd by many authors, differences between the techniques, or finally, differences in skewness. In our material the mean is approximately 3 kg above the median.

However, it should be noted that the female means given by Behnke are merely *approximations* based on Edward's skin-fold data and male/female ratios in guinea pigs, and not values based on actual determinations (*cf.* Garn, '57c).

In respect to the fat-free weights, the degree of agreement among the male series is exceedingly good, due perhaps to the fact that the fat-free weight is less influenced by nutritional status. The mean estimate for the Ohio men is 62.4 kg: Behnke assumes a mean of 62.7 kg for all age categories. The means of Brožek and Keys ('51) and of Miller and Blyth ('54) are within 1 kg of our estimate, while the mean fat-free weight obtained by subtraction from the data of Edelman *et al.* ('52) is 59 kg. The student group, at 61.5 kg also agrees well with data for men of comparable age. Here, however, the element of sampling stressed by Behnke, Edelman *et al.*, Osserman *et al.* ('50) and others is quite apparent. The farmers and farm-raised subjects in our Ohio series have a notably larger fat-free weight, 68.5 kg, quite like the mean of 68.9 kg reported by Miller and Blyth ('53) for physical education students. The more sedentary professional and clerical workers in our series approximate Brožek's mean for older males of "standard" weight. Obviously, more information than just height and weight should be given in the future when adding data on body composition to the literature.

The fat-free weights for the Ohio women encounter the same difficulty previously noted. Our mean of 44.6 kg is will below Behnke's standard of 49.4 kg, but equally above the mean of 40.0 kg obtained by subtraction from the data of Edelman *et al.* ('52). Further discussion at this time would be pointless, since the source of the inter-group differences is not known.

Interestingly, the women and the men are not too unlike in the weight of fat. Taking the median weight of fat for comparison as is preferred with such skewed distributions, women carry approximately as much fat as men. However, women are relatively considerably fatter (*cf.* Garn, '57b). Computed as per cent of total weight, percentage fat in the female is approximately 50% above the comparable value for the male, a female/male ratio exists in guinea pigs and possibly other mammals as well. But this particular method of computation, though the usual one, is open to objection. Fat may well be computed in relation to the fat-free weight and not as a percentage of gross weight since the common method of dividing the weight of fat by the gross weight, introduces the same value (fat weight) into both numerator and denominator. At low values of fat this procedure has little effect, but at fat values up to and exceeding the fat-free weight, it tends to conceal the true relationship. By way of example, an individual weighing 100 kg, with 50 kg of fat would have a percentage fat value of 50% by the ordinary calculation, but 100% if expressed in relation to the fat-free weight. Now if fat and fat-free weight were correlated variables, the former method might still be preferred: some value such as 14% for men and 20% for women might be the "norm" at all weight levels. But since fat and fat-free weight are uncorrelated in all adult series we have investigated to date, using the *fat-free weight* as the reference standard instead of gross weight, would appear to be preferable.

The present study emphasizes one problem, only partly explored in the reproducibility tests. How constant may we consider the fat-free weight to be? Here, we have asumed that it is relatively constant, within the span of a few years, and have used our experimental evidence as supporting the validity of the roentgenogrammetric method of determining body composition. However, just as there is some evidence for a decrease in the fat-free weight between ages 20 and 60 (which may be due to secular changes and not a true decrease at all), there is evidence that a gain or loss in fat involves supporting and vascular tissue. In this latter case, fat-free weight may be expected to be constant only within set limits, probably not larger than the experimental error of this or other techniques.

Further, it should be noted that all three techniques for the estimation of body composition involve the same assumption, that of constancy of density and/or composition of the tissues involved. Apart from experimental errors, including the determination of residual air, a major source of error in the densitometric method lies in the assumption that fat has the same density in all people, and at all ages. In the dilution method, the assumption of constancy in the water content of the fat-free mass constitutes a probable stumbling block, even with due correction for age. And in the x-ray method employed here, the assumption that a given thickness of fat may be equated with a given weight of fat remains to be tested. For clinical purposes, these qualifications may be ignored. A person with a low specific gravity, a low percentage of water, or thick pelvic fat is undeniably fat. But from a research standpoint, the constancy of the "constants" remains an open question; there is much work still to be done.

The roentgenogrammetric technique, like the dilution technique, is subtractive, in that it estimates the weight of one body compartment, and then approximates the remainder by subtraction. This, unfortunately leaves but one degree of freedom, and any error is repeated twice. As Siri has recently pointed out (Siri, '56), there is need for methods that can yield information on fat, on muscle—and other protein—and mineral too. One particular advantage of the roentgenogrammetric technique is that it can be extended beyond its present limits to yield independent estimates of fat, muscle, and bone.

The technique of estimating fat weight, from suitable x-rays has been mentioned before, and is described in considerable detail here. The roentgenogrammetric method also can be adapted to yield excellent approximations to the thigh muscle mass (*cf.* Garn and Gorman, '56), which should correlate well with total functional muscle, except in muscular dystrophies or motor nerve paralyses. And x-rays of the long bones are not only practical but with the work of Trotter already completed (Trotter, '56) they should provide information on a third body compartment, bone, or more specifically mineralized tissue. At the present time we are exploring the use of x-rays of the thigh section to provide the necessary data on a single 14 × 17 inch film, and without undue exposure to penetrating radiation.

SUMMARY

1. The weight of fat and the fat-free weight were estimated on an individual basis for each of 251 adult males and females, using the thickness of iliac crest fat for females and trochanteric fat for males.

2. Estimated fat-free weights both for a group of Ohio men (mean age 40) and a group of college-age males (mean age 21.7) averaged close to 62 kg, a value in agreement with data obtained by densitometry and blood-dilution on comparable groups. The female mean (44.6 kg) fell between the only two standards presently available.

3. The estimated weight-of-fat distributions were all highly skewed, indicating that the median was the appropriate measure of central tendency. However, using the means for comparison with published

data, both the Ohio men (mean weight of fat 13.4 kg), and the college males (mean 11.0 kg) were in close agreement with comparable series.

4. In the Ohio group the sex difference in the median weight of fat was small (0.8 kg). Percentagewise, however, the women were fatter, approximately 50% above the male. Expressing fat as a percentage of the fat-free weight not only differentiated the sexes better, but distinguished the few highly obese individuals whose weight of fat actually exceeded their fat-free weight!

5. The range of fat weights was 2.0 to 36.0 kg, thus the ratio of the most obese female to the leanest was 18:1. However, comparing the highest to lowest of the fat-free weight, the ratio was far smaller, being 2.0 in the females and 1.6–1.7 in the males.

6. Sorting the data in terms of stature groupings, a rise of 0.6 to 0.7 kg of fat-free weight per cm of stature was obtained. This may be taken as evidence that the effect of stature is not minimized by the present method although stature does not enter directly into the calculations.

7. Replicability studies were conducted on 10 individuals who had gained or lost up to 12 kg in weight. "Before" and "after" estimates of fat-free weight agreed closely with a maximum difference (in one subject) of 3 kg and a mean difference of less than 1 kg.

8. While emphasizing the fact that roentgenogrammetric determinations of body composition yielded results both reasonable and in agreement with other studies, the possibility of obtaining further data on body composition was suggested. In particular, suitable x-rays may provide estimates of muscle mass, and skeletal weight as well.

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LONGITUDINAL STUDY OF PLASMA FIBRINOGEN IN CHILDREN

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PLASMA protein studies are being made on a group of 88 children who are seen at regular intervals throughout their childhood years. The children have been followed for varying periods of time: the youngest child has been seen from age one month through three years and the oldest, from age 7 through 19 years. Each child lives at home with families which are generally of the upper middle class, and is brought to us for study. At the time blood is taken, each child has a complete physical examination and x-ray studies of chest and sinuses. A history sheet is kept by the parents for the interval between examinations recording illnesses, immunizations, etc. Physical examinations and interval histories have been done on most of the children from birth but in several instances, blood work was not started until a later age. Dietary histories have been taken by a trained nutritionist on 43 of the subjects. Determinations of blood constituents are done at one, two, and three months of age, then at three-month intervals to three years, and at 6-month intervals thereafter. Capillary blood is used in the younger children and venous blood at later ages when the child becomes cooperative and has a readily accessible vein. Several determinations are made on each sample of blood, including plasma proteins as separated by a salting-out technique (Hill and Trevorrow, '41) and Tiselius analysis on the venous sera. There is also a complete hematological study, including sedimentation rate.

In all, 2180 determinations of fibrinogen have been made. Of these, 1663 remain as acceptable analyses made during periods of health after elimination of three groups of values: (1) 409 determinations during or following a possibly significant illness, (2) 22 which we term "subclinical" illness, and (3) 86 possibly questionable for analytical reasons. The last group was determined by calculating for each individual the relationship between his sedimentation rate and the salted-out plasma proteins according to the method described by Meyers ('53) and discarding each determination outside the limit of two standard deviations. It is of interest that the discrepancy was predominantly in the direction of too high a sedimentation rate (75% of healthy and 90% of ill children) and that in 15 instances where Tiselius analyses were done, 11 showed a high alpha-2 globulin, a fraction which does influence sedimentation (Meyers *et al.*, '53). Since the cause of the discrepancy could not be determined in the majority of values in Group 3, all 86 determinations have been discarded. The 22 values in Group 2 represent instances in which there were no positive findings on examination and no significant illnesses, accidents, or immunizations reported on the interval history, yet the laboratory findings showed both sedimentation rate and plasma fibrinogen and/or globulin to be definitely elevated from the usual level and variation shown by the individual. It is possible that a significant event was not recorded on the history, although many were checked by additional consultation with the child and parent at the time of the determination. It seems more likely that this group represents reaction to infection which was overcome without recognized symptoms. Group 1 was chosen by an independent analysis of the pediatric material. It consists of all children who are found at the time of examination to have some inflammatory process, usually, but not always, associated with purulent discharge, or who had recovered from such a process within not more than one week prior to examination.

Within the group of "healthy" determinations there is no difference in fibrinogen levels between boys and girls. A trend with age is shown in chart 1 which depicts the 25th, 50th and 75th percentiles as smoothed by inspection. The median level at one month is 0.205 gm/100 cc which is followed by a rapid drop to a low of 0.145 gm/100 cc at 6 months and then a rise to 0.190 gm/100 cc at the limit of our age reliability at 17 years. In this analysis, each age group from one month through 12½ years contains from 31 to 58 individuals, with decreasing groups to 12 individuals at 17 years. The lowest absolute value for fibrinogen is 0.04 gm/100 cc and the highest, 0.37 gm/100 cc. Twenty-six determinations are 0.30 or higher, two of which are over 0.35 gm/100 cc.

After the sharp decline in the first half year, there is an increase in fibrinogen concentration for the group as a whole up to two to three years of age. We then see a relative plateau for the next two or three years, followed by a slow, gradual rise to 17. Whether the plateau is real is open to question, however, it seems to be present at each quartile level. The physiological significance of the age changes is not understood and it should be mentioned that individually the children do not conform to the average pattern, but deviate both in slope and in timing. Nevertheless, since the period of life studied on the 88 subjects has not been identical, and we must therefore compare children seen over different spans of age, each value on each child has been considered in relation to the median trend for the entire group.

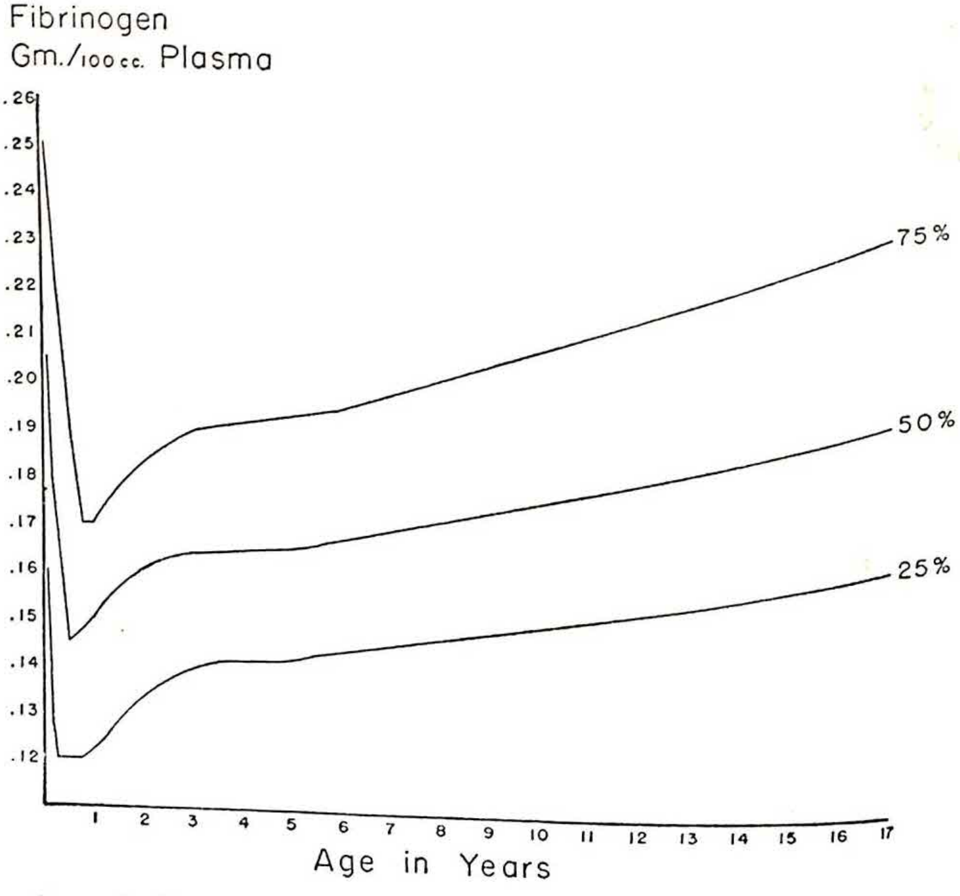

CHART 1. THE PERCENTILE DISTRIBUTION OF PLASMA FIBRINOGEN CONCENTRATION AS IT VARIES WITH AGE.

For each individual we have calculated the mean and standard deviation of "healthy" values in terms of their deviations from the age median for the group as a whole, with the number of determinations per child varying from 10 to 29. The subjects differ in level from the lowest mean value of 0.059 gm below the age median to the highest of 0.078 gm above the median. They also differ in variability with standard deviation from ± 0.018 to ± 0.067, which difference is not a function of age. The level followed by an individual does not correlate with the variability; that is, children tending to high fibrinogen levels do not vary about their own mean values either more or less than those at low levels.

The question of the significance of the differences between children has been examined from several points of view. With respect to the difference in variability between individuals, Bartlett's test for homogeneity of variance (Snedecor, '46) on either the original observations or the observations expressed as deviations from the age trend line indicates a lack of homogeneity of variance at a level of significance of less than 0.001%.

It was expected that the variability shown by an individual might be related to environmental factors. If this be so, our data do not give conclusive evidence implicating factors of incidence or duration of respiratory illness, or frequency of exposure as it is determined by the number of siblings. There is a tendency for the least variability to be in the first born or only child in the family. These children also tend to have a less than average incidence of infection. Neither of the above relationships is significant at the 5% level. For example, in 8 families we have followed each of the first two children through the period from age 6 months through 4 years. In 6 of the 8, the younger child shows more variability than does the first born of the same family. In this comparison, variability is defined as the error mean square for linear regression of fibrinogen against age as calculated for each child. The probability of this distribution of results is $P = 0.144$, which may indicate a relationship, but is not significant at any usually accepted level.[1]

An exact test for the significance of the differences among means for the entire group of 88 children is not possible by any known statistical procedures unless one ignores departures from the assumptions underlying these procedures. These assumptions require that individuals and observations be independent, that the individuals show equal variability, and that the observations on each child approximate a normal distribution. None of these, with the possible exception of the independence of the individual observations, appears to be true for our data. In addition, we have considered values in relation to the age trend in order to remove age, *per se,* as a factor. This technique assumes that each child follows this average pattern, which, as stated above, is not always the case. If we forego statistical analysis and examine the material graphically, we find that one child at the upper end of the distribution has been consistently above the group median over a span of 11½ years, and another child has no "healthy" value above the trend line over a 10½ year period, each child having been followed from infancy to his present age. As further demonstration of the thesis that an individual tends early in life to establish a level of fibrinogen which he maintains during periods of good health and to which he returns following elevations resulting from illness, we have calculated the mean healthy level for each child during his 2nd, 4th, and 11th years and compared these periods. Chart 2 depicts the relationship between the 2nd and 4th years, and chart 3 shows those children who were seen in their 2nd and 11th years. This approach would seem to indicate that a level is established by the second year.

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[1] We have tested approximately the hypothesis that there is no difference in variability between siblings against the one-sided alternative that the variability of the younger sibling exceeds that of the older, by testing, for a binomial with $N = 8$, the hypothesis $p = ½$ against the alternative $p > ½$.

We have next tried to correlate the illness record in the first two years with the childhood fibrinogen level. Severe respiratory illness has been used as the measure of illness since other types of infection have been too uncommon to offer any reliable data. Other miscellaneous diseases, immunizations and allergy will be mentioned later. The presence or absence of siblings has been considered since their presence is believed to increase exposure to infections. One half of the group (43 children) with higher childhood fibrinogen levels have a history during their first two years of 36 acute upper respiratory infections with fever compared with 28 infections in the half with lower fibrinogen levels, several in each group having no infections other than a mild runny nose during the two year period. For those children having older siblings, 27 with high fibrinogens show 23 infections and 22 children in the low group suffered 19 infections. A similar study was made of the health history during the first six years of life for all children who have reached this age. The results are summarized in table 1. Here again the frequency of infection does not vary with the fibrinogen level. Thus, the frequency of infection does not appear to be a determining factor in setting the fibrinogen level, and conversely, the fibrinogen

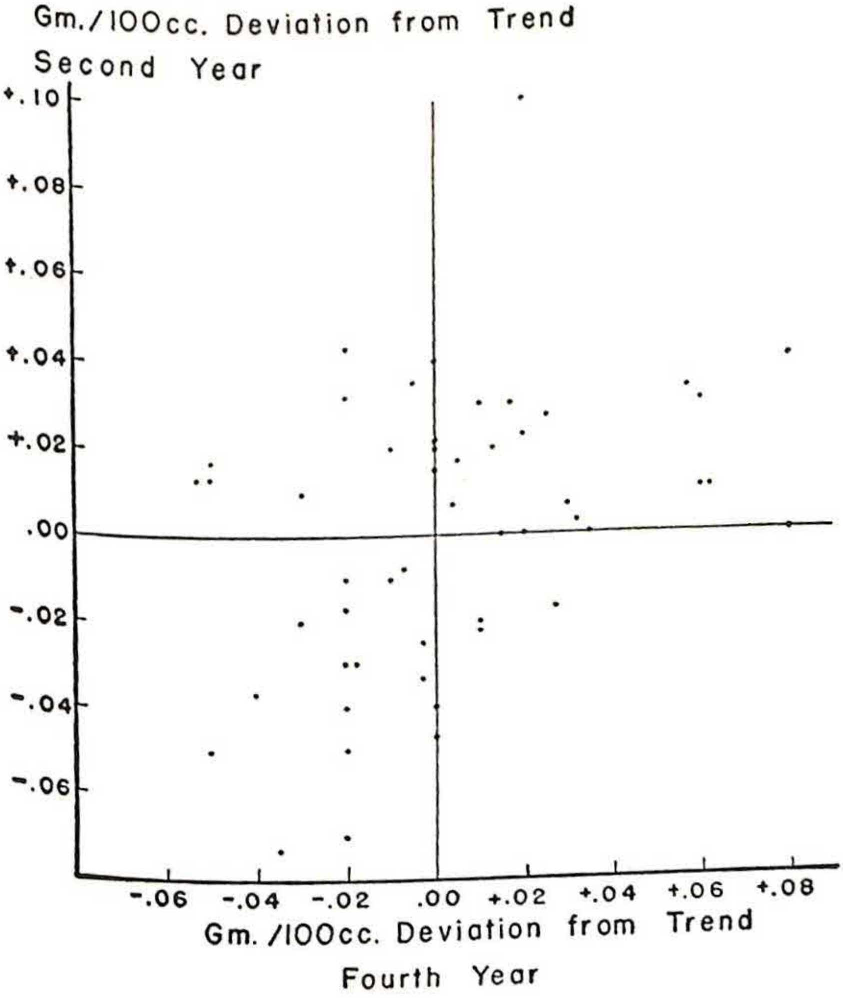

CHART 2. FIBRINOGEN CONCENTRATION IN THE SECOND YEAR OF LIFE COMPARED WITH THE VALUE ON THE SAME INDIVIDUAL IN THE FOURTH YEAR.

level at the time of exposure to disease does not alter the frequency of infection. Similarly there is no correlation between the mean duration of respiratory infection and the healthy level of fibrinogen, as shown in table 2. It is apparent that the pre-exposure level of fibrinogen bears no relation to the course of the disease. With respect to

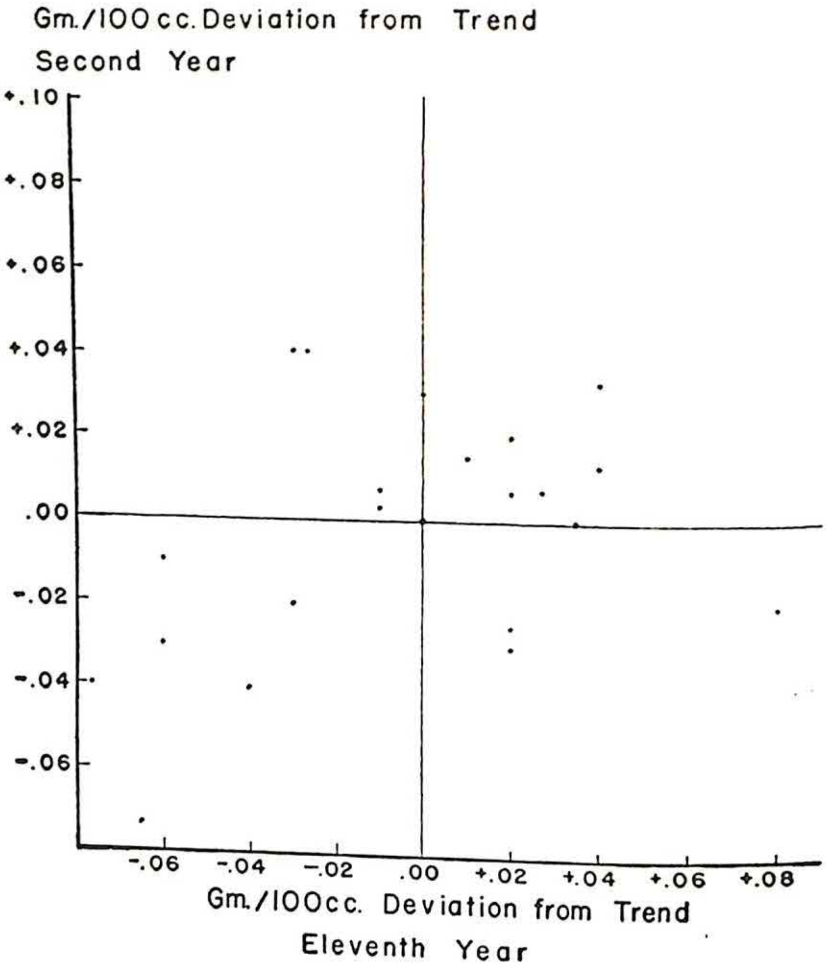

Chart 3. Fibrinogen Concentration in the Second Year of Life Compared With the Value on the Same Individual in the Eleventh Year.

TABLE 1

Number of children showing indicated frequency of severe respiratory illness during the first six years of life.

	HIGH FIBRINOGEN		LOW FIBRINOGEN	
	1st born	Older sibling(s) in family	1st born	Older sibling(s) in family
Three or more illnesses	7	14	10	13
Less than three illnesses	8	7	10	7

childhood diseases and infections other than respiratory, the high and low fibrinogen groups are equally divided with 29 of 44 children in each group free from these infections. Definite allergy was present in 28 of those with high fibrinogens and in 26 of the low group. Our subjects offer no opportunity to study the effect of immunization, since only three children are known to have received no immunization during the first two years.

In addition to the differences between children in level and variability of fibrinogen during health, there also seems to be a difference in their responsiveness to illness. On 17 occasions an infant was seen within 7 days of D. P. T. immunization. In 12 of these, the fibrinogen was at or above the level of plus three standard deviations from the child's healthy mean value; in three, the level was plus two standard deviations, and in the other two, there was no significant fibrinogen increase. Among older children, one boy was seen between 6 and 19 years of age with pink eye on one occasion and twice within 7 days of an upper respiratory infection with fever. In all three instances his fibrinogen rose to above the plus three standard deviation level. In contrast, another child between the ages of three and 8 years had pink eye with no response and was seen on 4 occasions within 7 days of an upper respiratory infection with fever, showing no response in three of the 4 illnesses. If one considers this apparent difference in responsiveness in relation to the health history, one again finds no correlation. For example, 10 children who have always shown an elevated fibrinogen following infection are compared with a group of 14 who have not shown such an elevation and who have each been seen on at least two occasions when such a response was expected. In the responsive group, 60% have average or less than average incidence of

TABLE 2

Number of children showing indicated mean duration of severe respiratory illness during period of study.

	HIGH FIBRINOGEN	LOW FIBRINOGEN
Duration average or above	17	19
Duration less than average	23	20

respiratory infections while in the non-responders, this is 58½%. The responding group have a mean duration of illness of —0.03 days from the average for all children whereas the non-reacting group average —1.16 days but deletion of one child with 11 short, treated illnesses changes this mean value to +1.00 day.

The 43 children on whom there is an adequate dietary study show no correlation between fibrinogen level and protein intake. Chart 4 shows the relationship between siblings in their fibrinogen levels. It is of interest that the pair marked "J," with low fibrinogens both have a higher protein intake than the pair marked "C" who are both at the upper end of the fibrinogen distribution in spite of a relatively low

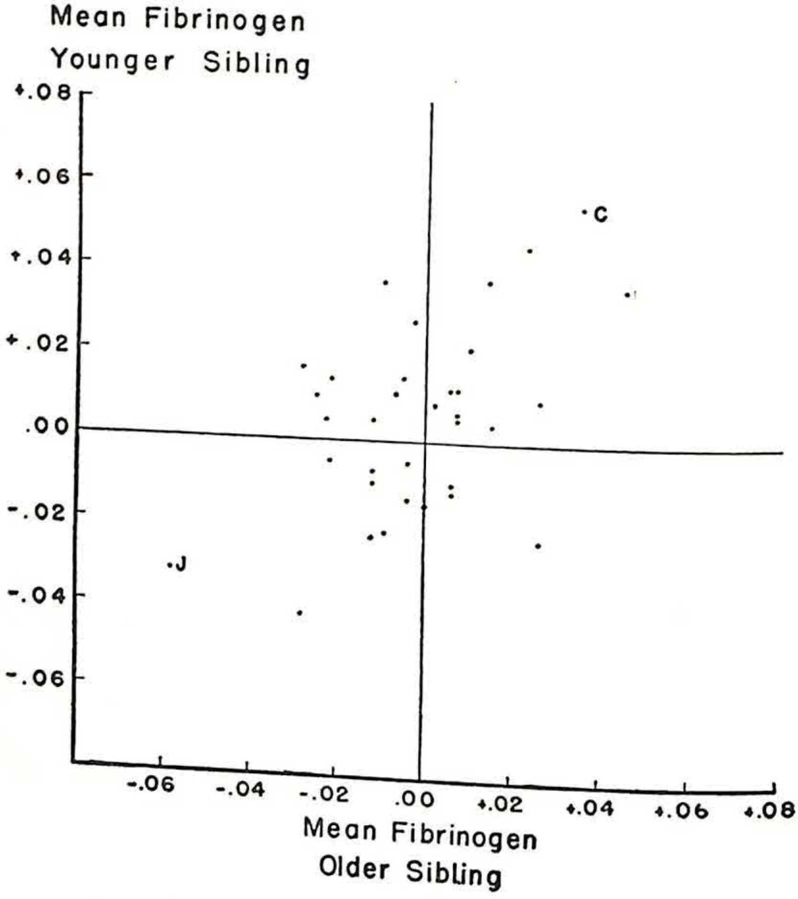

CHART 4. COMPARISON OF CHILDHOOD FIBRINOGEN LEVELS BETWEEN 34 PAIRS OF SIBLINGS IN 24 FAMILIES.

protein intake as compared with standards based on a study which includes these 43 subjects (Beal, '53). This inverse relationship does not hold for the group as a whole. Ham and Curtis ('38) have shown that extremes of protein intake can influence fibrinogen levels in a positive direction, however, it should be pointed out that our subjects all receive a diet which is considered to be adequate: none is clinically deficient, and probably none has ingested protein in amounts as high as the supplemented diet used by Ham and Curtis.

We believe that individuals do differ in their level and variability of fibrinogen during health and probably in their fibrinogen response to illness. Insofar as these differences have not been accounted for by environmental factors, as expressed in the health and diet histories, it would appear that the explanation may lie in a difference in physiology, possibly genetically controlled. Within our series of children there are 24 sets of siblings, two or three in each family. Such a group is not subject to any statistical proof of genetic determination; however, that such a possibility exists is demonstrated in chart 4. This chart graphs the older sibling against the younger child for 19 families with two children and 5 families with three children, giving a total of 34 pairs. The probability that such a distribution should result from chance alone is about 0.05 by either the chi square test or the corner test of association (Mood, '50). It would appear that families, in some instances, do tend to show an intra-family similarity in the fibrinogen level of the children, and do show real differences between families. If families are different, then our view that individuals within the whole population show real differences, is further substantiated. As with individuals, the families who are distinctly high (upper three families) do not show a consistent difference in health pattern from those families who are distinctly low (lower two families). Within these families which tend to show sibling similarity at the extreme levels, the health histories within any given pair of siblings are often quite different. For example, one family with low levels shows the older boy with 5 significant illnesses in 13 years, with an average duration 4 days longer than that for the group as a whole; the younger boy has had 8 significant illnesses in only 10 years, but each has been of shorter than average duration. Both boys are allergic. In a family with high levels, the older girl has had 8 illnesses in 7 years, with a mean duration one day shorter than average, while her younger brother had only one illness in 5 years but that was of long duration. Only the younger child is allergic. The intra-family relationship does not result from similarity of known environmental factors, and may therefore be of genetic determination.

The genetic control of fibrinogen synthesis has been discussed by many workers in relation to those cases where the level is low enough to interfere with normal clotting. A bibliography to this work is presented by Graham ('56). The present longitudinal study of fibrinogen might indicate that genetic control exists within the "normal" range of values as well as in the abnormal case of afibrinogenemia.

SUMMARY

Plasma fibrinogen has been determined in a group of 88 children who were followed longitudinally over a period of several years. Physical examinations including x-rays have been done on each child from birth, complete health histories are available on 86, and records of dietary intake on 43 of the subjects. Complete hematological examination including sedimentation rate was done on each blood sample. One thousand six hundred and sixty-three fibrinogen analyses were done on the children during periods of health with the number per child varying from 10 to 29.

The level of fibrinogen changes with age. These changes are described for ages from one month to 17 years.

Individuals differ from each other in their level of fibrinogen, in their variability, and possibly in their fibrinogen response to infection. These differences show no correlation with frequency or duration of infections, sibling position in the family, or protein intake.

The level of fibrinogen does tend to be similar within the children of some families. Insofar as known environmental factors have not correlated with the fibrinogen level, it may possibly be genetically controlled.

ACKNOWLEDGMENT

The author, who contributed the plasma protein studies, thanks other members of the staff of the Child Research Council for making available and analyzing their data in the fields of pediatrics, hematology, x-ray, nutrition, and biometry.

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BOOK REVIEWS

A Symposium on the Chemical Basis of Heredity. Sponsored by the McCollum-Pratt Institute of the Johns Hopkins University with support from the Atomic Energy Commission. Edited by W. D. McElroy and Bentley Glass. The Johns Hopkins Press, Baltimore, 1957. xiv + 848 pp. $12.50.

This volume consists of papers and discussions presented at a symposium held at the Johns Hopkins University June 19-22, 1956. Those who attended this or any of the previous symposia, or read the 6 volumes of the proceedings, will not need to be told how valuable and stimulating is the product. Those unfamiliar with the series should be informed that this is an important book.

The book is divided into 8 sections. The titles of the first 7 sections are: Cellular Units of Heredity; Role of the Nucleus; Nucleic Acids and Associated Substances in Cell Division and Protein Synthesis; Nucleic Acids as Transforming Agents; Viruses as Bearers of Heritable Characteristics; Nucleic Acids—Chemical Composition and Structure; Synthesis of Nucleotides and Nucleic Acids; and Mechanism of Duplication. A section generally contains about 6 papers, plus one or more discussions, although the seventh consists of but two papers. The eighth and last section is a summary by Bentley Glass (77 pages).

The authors and editors have given us a very useful and dynamic presentation of our present knowledge of the chemical nature of the basic genetic material, the way nucleic acids may control their own autoduplication and the synthesis of proteins, and much else besides. Merely from the list of topics covered it is apparent that the result is a valuable summary of contemporary work in several related fields which together constitute a subject in which, one cannot help but believe, a decisive break-through is to be expected in the near future. As a basis for the understanding of this advance, this volume may well be indispensable. In the meantime no scientist interested in the problem of the chemical basis of heredity will want to be without the book. It should be said, however, that this is not an ideal introduction to the subject for the beginner, since the authors, being authorities in their respective fields, and speaking primarily for the benefit of their colleagues, devote little time to elementary introductory matters and generally plunge immediately into a presentation of their own contributions and ideas. A diligent study of the summary might help somewhat to remedy this relatively minor drawback, but on the whole the non-specialist should take up the Symposium realizing that he may find parts of it hard going.

Fifty-six authors were responsible for the papers presented, and this seems too long a list of names to give here: they are all outstanding workers in the fields represented, mostly Americans, naturally, but including some distinguished investigators from abroad. It would be invidious, and not a little difficult, to single out any particular paper or papers as the best or most important. The interested reader will want to read them all.

There is an author index, a subject index, and a list of additional participants.

WILLIAM C. BOYD

Boston University,
School of Medicine,
Boston, Massachusetts

Immunology and Serology. By PHILIP L. CARPENTER. viii + 351 pp. W. B. Saunders, Philadelphia and London, 1956. $6.50.

Blood Group Substances: Their Chemistry and Immunochemistry. By ELVIN A. KABAT. ix + 330 pp. Academic Press, Inc. New York, 1956. Price $8.00.

These two books are almost exactly the same size, they were published at about the same time, and they deal with closely related subjects; yet in treatment they differ almost as widely as two serious scientific books can. Dr. Carpenter writes as a teacher; he leads us painstakingly through the vast field of immunological knowledge over carefully graded highways, but it is only from a distance that we are allowed to see, dimly, the borderland of existing knowledge. Dr. Kabat, on the other hand, as a pioneer investigator, leads us very rapidly over the long-established facts, straight to the incompletely surfaced roads which border the frontier.

Dr. Carpenter's book is carefully written; unlike the authors of so many modern text books he has thoroughly assimilated and co-ordinated the facts himself before setting them down. In so far as I can judge a book that deals mainly with matters outside my own specialty, I think I can recommend it as a sound introduction to immunology and serology.

A glance at the references, however, shows that few of them are dated later than 1950; and several important recent developments in immunology are mentioned only briefly or are omitted entirely.

On the use of precipitin reactions in the taxonomic classification of animals one would have welcomed some account of the work of Weitz and of the more recent developments in the work of Boyden. The description of the serological classification of plants is most welcome, as it is not generally known, but some mention should have been made of the presence of specific hemagglutinins in the seeds of many plants.

In the description of the human blood groups scarcely any mention is made of the vast amount of work done in the past 10 years: characteristically, the one specific recent discovery mentioned is the introduction of a technique, that of enzyme treatment of red cells to promote agglutination. The account of the anthropological application of blood grouping is completely out of date.

No mention is made of the existence of specific blood group hemolysins in the serum of various species of mammals including man; we are not told that most cattle blood grouping tests are carried out by a lytic technique, nor of the first discovery of iso-immunisation by Ehrlich and Morgenroth in goats which involved the production of such lysins, and was made within a few months of the discovery of the human blood groups by Landsteiner.

The most serious omission of all, however, is that of any mention of acquired immune tolerance. The development of the subject is admittedly recent, but blood group chimeras have been known in cattle since 1945 and in man since 1953. The literature of acquired tolerance to tissue grafts is already extensive and is leading, in the hands of such workers as Burnet and Medawar, to a fundamental transformation and enrichment of the whole theoretical background of immunology. The former of these has introduced the idea that the organism recognizes certain immunological markers which tell it whether a substance is ‘self’ or ‘not self’; it tends to make antibodies to the latter. If, however, a foreign substance is introduced to the organism at a sufficiently early stage of the latter’s development, it becomes accepted permanently as part of the ‘self.’ This suggests that the ability to distinguish the ‘self’ is actively acquired and not passively inherited.

No misprints have been noted in the text. Among a dozen references checked, one numerical error was found, and the author and printer have failed before the shibboleth of the name ‘Ingebrigtsen.’ This is the fourth work in which I have come across references to this author, and in every case his name has been misspelled.

Blood Group Substances is a much harder book to read but much more rewarding to those who make the effort. Dealing with a narrower field, it does so in a very thorough manner; the literature up to the beginning of 1955 is covered with admirable completeness, but the book is no mere catalogue of publications—every fact is clearly and concisely related to the whole field. There are over 1,200 references; those checked proved correct.

The first chapter is a higly concentrated but remarkably complete account of present-day knowledge of the blood groups, especially those of man. The second describes standard techniques used in blood grouping, as well as some of the methods used in investigating the structure of the blood group substances. The ground of the first chapter and most of the second is already covered by other books but it is useful to have the material brought together here as an introduction to the more specialized part of the book. Subsequent chapters deal with the sources of blood group substances, their purification, their chemical composition and immunochemical characterization, and differences between substances derived from different animal species. A long chapter describes changes produced by various reagents, and the attempts which have been made to determine the precise structure of the substances. Another describes the blood group antibodies, their reactions with the antigens, and their biological effects, and the last deals in a broad way with the biological significance of the blood group substances. This last chapter is of greater general interest to biologists than the others but can scarcely be understood without some knowledge of what has gone before.

The blood group substances clearly play a much more important part in the scheme of living things than is implied by their name. Considering only the substances of the ABO system, in man they are present in a variety of tissues and, in most people, are poured out in vast quantities in the mucous secretions. Similar substances are found in the red cells, tissues and secretions of many, possibly all, vertebrates, while closely related substances are present in certain plants, and in the capsules of bacteria. Antibodies which react specifically with the blood group substances occur not only in human and other mammalian sera but also in extracts from the seeds of a variety of plants, mostly leguminous.

Our knowledge of the composition and structure of the blood group substances is mainly due to the work carried out in the laboratory of the author, and in that of Professor W. T. J. Morgan in London. The residues, consisting of monosaccharides and amino-acids which go to make up the complex molecules, are now almost completely known and a beginning has been made in elucidating their arrangement, especially in that part of the molecule which determines their specific serological properties.

We do not know the function of these remarkable substances, though the differential incidence of certain diseases in relation to the blood groups must be an important clue. The author mentions a similarity between the blood group substances, and the intrinsic factor which is deficient in the gastric secretion of cases of pernicous anemia: since the book went to press a statistical excess of group A individuals has been found among sufferers from this disease. Several other substances of physiological importance, such as chorionic gonadotrophin, show chemical and immunological resemblances to the blood group substances, the study of which may help to reveal the function of the latter.

Another outstanding problem is that of the mechanism whereby the blood group genes determine the complex chemical structures of the corresponding substances, but there are indications that the H substance, found mainly in the secretions of O persons, is a basic molecule upon which the A or the B " stamp " may be impressed by the corresponding gene.

To all those who are interested in serology and possess a basic knowledge of organic chemistry this book can be strongly recommended.

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Human Ovulation and Fertility. By EDMOND J. FARRIS Philadelphia: J. B. Lippincott Company, 1956. $6.50.

In this book, Dr. Farris expresses the commendable hope that by and from it the infertile couple will be helped to attain the joy of family fulfillment.

Because " normalcy," evidenced by the absence of obvious faults as revealed by the histories and examinations of both the man and woman, does not of itself assure the success of a mating, and because the human species does not exhibit oestrus as one recognizes it in many other mammals, the author stresses the proper timing of coitus as a matter of primal importance. He briefly alludes to the several conventional criteria of ovulation and then goes into considerable detail over the rat-ovary hyperemia test with which he has had rather singular success in establishing the fact and time of ovulation in women.

Excellent correlations are described between the hyperemia test and the appearance of the ovaries, notably the follicles and corpus luteum, and of the endometrium as revealed at operation. Interesting to note was the measured increased amount of voluntary muscular activity at the time of ovulation, a phenomenon commonly observed in domestic animals at the time of oestrus. The hyperemia test is dependent on the close adherence to essential precautions. Rats of a specified strain are required. Positive or negative results are based on color changes induced in the ovaries in response to the injection of urine at different phases of the menstrual cycle. The rats must be killed with illuminating gas of a special composition, and the ovaries must be inspected under special lighting conditions. Resultant degrees of redness are compared with those of the Munsell color chart. That the test can be read within two hours after the injection is an obvious point in favor of this method.

In the author's experience the high incidence of conceptions resulting from isolated coitus based on proper timing, which in turn was based on the hyperemia test, would bespeak of the advantage of the method. According to the data, 92% of the conceptions occured between days 10 and 16 of the menstrual cycle. When artificial inseminations were employed on the alleged days of ovulation, based on the hyperemia test, 35% of the 100 conceptions followed single inseminations—a truly remarkable achievement. Many clinicians would, however, be opposed to the author's method of injecting the semen into the uterine cavity. Still more extraordinary is the assertion that 96.5% of the women become pregnant by the 3rd homologous insemination, and 73% by the heterologous procedure. It would be of interest if other workers could accomplish so successful a feat. Dr. Farris states that the average length of menstrual cycles is so constant that only three consecutive cycles are necessary from a practical standpoint to establish a pattern. This conclusion is inharmonious with the incidence of failure, *i. e.*, the large number of unwanted pregnancies which result from the employment of the "rhythm" or the so-called "safe period"—evidence of variations in the cyclic patterns which the experienced obstetrician will attest. This being so, one questions the practical advantage of employing the hyperemia test when simpler methods for timing ovulations are available.

While one admits that the functional life span of the unfertilized egg is brief, this fact hardly warrants the recommendation that coitus should occur at a specified hour by day or night to be successful, save in the woman of greatly diminished fertility. Elsewhere the author offers practical hints for improving the pattern of ovulation. The familiar advice of adjusting the basal metabolic rate is again given. However, the great benefits claimed of pituitary irradiation has just as ardent opponents.

All in all, this book offers some practical advice helpful for the couple which desires to achieve a pregnancy. The reviewer feels that the author has had truly unusually good fortune in the treatment of infertile couples, but feels that some of his several formulae are oversimplifications of the very complicated problems of fertility. Important as is the timing of ovulation, the realms of endocrinology and other environmental factors of the reproductive tracts of men and women do not receive the attention they warrant, but perhaps Dr. Farris's main objective was to emphasize the merits of his hyperemia test.

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Rochester, New York

Life Tables From Limited Data. By GEORGE J. STOLNITZ. 164 pp. Office of Population Research, Princeton University. 1956. $4.00.

This book contains an exposition of the methodology which the author has developed for constructing life tables when primary reliance has to be placed on information obtained in a single census. Conventionally, life tables are based on age-specific rates derived from population and mortality data by age. There are circumstances, however, when data on deaths by age are not available or are of doubtful validity and substitutes for them can not be derived from successive censuses. The single census methodology probably has greatest application in underdeveloped areas having only scattered censuses. In addition, several potential applications of life tables based on the single-census approach are listed in the final chapter of the book.

After briefly discussing the plan of the book in Chapter 1, the author presents in Chapter 2 the general analytical scheme for constructing life tables from a single census. Of foremost importance to this scheme is the development of formulas for computing age-specific survival rates. These formulas require a knowledge of the comparative experience of successive pairs of age groups. It is significant that they depend on ratios rather than frequencies since the former are much easier to estimate than the latter. Even so, estimates of birth survival and population ratios for successive pairs of age groups would rarely be available directly for areas utilizing the single-census approach to compute life tables. The discussion in Chapter 3 relates to problems of estimating birth and survival ratios by indirect means involving the use of substitute data provided by other areas having similar demographic characteristics. The discussion in Chapter 4 relates to methods of adjusting the population ratios so that they correspond to the birth ratios and are free from the effects of past migration.

It is basic to the author's approach that sufficient safeguards exist to insure the rejection of life tables when the single-census approach produces intolerable errors. In Chapter 5, he presents some guides for detecting major inaccuracies in the age-specific rates from a knowledge of the typical variations in these rates between the sexes and by age. The results of an empirical test of the single-census approach are discussed in Chapter 6. Forty-seven life tables were prepared for populations representing a variety of statistical and demographic circumstances for which conventionally computed life tables are available. The author concludes that most of the estimates of survival rates erred by less than 2% at ages under 50 years and that beyond age 50, the probable range of errors tends to increase with rising age to about 5 and 10% at ages between 60 and 70. Estimates of the average duration of life between 2.5 and 67.5 years in these experiments fall within 5 to 6% of the correct values and all but a small minority fall within 10%.

Two new life tables for the American native-white population about 1890 and the native population of Brazil about 1940 are presented in Chapter 7. The chapter contains a detailed exposition of the adaptation of the single census approach to these two populations lacking adequate mortality data and presenting very different problems in estimating birth, survival and population ratios needed in order to compute age-specific survival rates.

In summary, the author has formulated an approach for constructing life tables which should prove useful in many circumstances where mortality data for the population groups under study are missing or are inadequate. He has indicated that this approach which places primary reliance on information found in a single-census frequently produces usable statistics. Moreover, he has provided a system of direct and indirect checks to insure the probable rejection of the life tables results when they are prone to excessive errors. The author has done his job well, and he has provided the potential appliers of this methodology with an excellent reference book.

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Tobacco Smoking Patterns in the United States. By William Haenszel, Michael B. Shimkin, and Herman P. Miller. viii + 111 pp. U. S. Public Health Monograph No. 45. Washington, D. C., 1956. $0.60.

Smoking has a variety of aspects that are of biological and medical interest and significance. The present monograph provides a comprehensive documentation and analysis of smoking patterns in this country. The primary data for this survey were provided by a supplement to the Current Population Survey of the Bureau of the Census for the month of February, 1955. The data were tabulated by current and lifetime smoking patterns. Special attention is paid to "mixed smokers" who regularly use more than one form of tobacco and to those who discontinued smoking. Cross-tabulations are presented with standard census categories including sex, residence, geographic region, race, employment status, marital status, etc.

The procedures for gathering the data were the same as used by the inter-census surveys. As the survey was conducted during day-time, when a large number of men were not at home, self-response rates for men fell as low as 58 percent. The validity of the history data for those not responding for themselves is open to some question; comparisons on some variables indicate fairly consistent underreporting of the occurrence of the smoking practice. The extent to which bias is carried over to estimates of such factors as age-started-smoking and age of maximum use is not indicated. Use of the basic American Cancer

Society questionnaire, with small improvements designed to reduce ambiguity, provided needed continuity with other work that has been done.

The monograph includes a complete appendix with detailed cross-tabulations. An addendum by Milmore and Conover gives a concise picture of the history of the use of tobacco in the United States from 1880 to 1955. Although the primary use of the data may be epidemiological exploration, other uses suggest themselves. The data provide the basis for selection of stratified samples for study of particular smoking patterns. For example, if one wished to study multiple smokers, these data would show in which population groups multiple smokers are most prevalent. It is hoped that social, as well as biological medical scientists, will find this a useful source of documentary information and of further research problems.

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Toward a Unified Theory of Human Behavior. Edited by Roy R. Grinker and Helen MacGill Hughes. xv + 375 pp. Basic Books, New York, 1956. $6.50.

As more and more fields of scientific enquiry split off from philosophy after finding each its own way of studying experimentally an aspect of the universe, each in turn goes through a period in which philosophy is regarded with disdain and suspicion. As the time required to learn the techniques peculiar to the young but growing science increases, the time for broader education (which might include philosophy) decreases and the specialization becomes deeper but narrower until finally in many areas technical skills threaten to predominate and contact is lost with the larger issues.

Every now and then better minds revolt against the isolation and fragmentation imposed by this specialization of science and an attempt is made to regain an overall view. Such a revolt can take many forms: an individual scientist can turn philosopher and write about matters, strictly speaking, outside the domain of his special competence. The quality of his mind is usually such that we enjoy reading the products of his leisure-time thought. One thinks of Einstein, Alexis Carrell, Max Born, Fulton and many others. At other times an attempt is made to build bridges between several disciplines by organizing an interdisciplinary journal such as *Studium Generale* or an interdisciplinary conference or symposium. Occasionally one individual works out a new concept which, for a time, brings several unrelated domains together. Selye's adaptation syndrome, Shannon's information measure, Cannon's homeostasis were such concepts acting in the manner of a searchlight directed toward a famous building: if skillfully placed, it throws new facets of the familiar landmark into thrilling relief.

This reviewer missed that rare quality during the reading of *Toward a Unified Theory of Human Behavior*, an account of the first four conferences of a group of behavioral scientists meeting from time to time to search for common theoretical ground in the behavioral sciences. The text is not a verbatim copy of the presentations and discussions, but rather an extremely well edited condensation.

The individual presentations range from compact summaries of some key concept to attempts to develop a hierarchy or system of concepts. Each speaker seems to have expected on the part of the other participants a great deal of familiarity with the ideas he presented. Not a single paper could stand on its own as an introduction to a theory of behavior or to a field of research, as was done in the 1952 Oxford Conference on Mental Health (*Prospects in Psychiatric Research*, J. M. TANNER, ed., Blackwell, London, 1953) or the early Josiah Macy symposia.

Perhaps the paper by Laura Thompson who sketches how anthropologists are struggling to find a culture concept which will unify them or Florence Kluckhohn's summary of 5 key problems to be solved in any Weltanschauung come closest to giving a completed whole. Roy R. Grinker, John P. Spiegel, and David Shakow each in turn indicate some analogies between psychological and group phenomena while Jurgen Ruesch reviews some concepts of communications theory as does Karl Deutsch.

Talcott Parsons introduces 4 laws from his general theory of actions and mentions the problem of the relation between the small group and the larger social system. Jules Henry develops some suggestive equations to describe relations between reward and punishment and between psychological commitments and fulfillments. James Toman reviews some of the multiple origins of the uniqueness of human society and discusses the complementary roles of stability and adaptation as dynamic reciprocating mechanisms in the service of evolution. Alfred Emerson underlines the fact that homeostasis is compatible with or may even encourage increase in variability whereas Anatol Rapoport looks at homeostasis from the vantage point of mathematical biophysics and spells out the concept of statistical boundaries.

Lawrence Frank pleads for a place for the culture concept and field concept and, most challenging of all, for the inclusion of the concept of growth and individual development within the unified theory. It was after this paper that the discussion became the most interesting and here probably the idea was first conceived of testing the applicability of concepts obtained from the study of biological heredity to theories about cultural transmission which led later on (after further discussions at the Stanford Center for Advanced Study in the Behavioral Sciences) to an exciting paper by Gerard, Kluckhohn and Rapoport on analogies between "biological and cultural evolution" (Behavioral Science, *1*(1): 6-34, 1956); ideas which also led to a series of experiments at Michigan on changes in problem solving "culture" in small groups with continuous replacements of individuals, imitating on a small scale the gene pool with its relative independence from particular individuals.

Reactions to this volume will vary. Some individuals may not be able to finish reading it, while others will praise it highly. In taking a middle position let us summarize some of the criticisms first.

a. There is at times too much display of the qualities exposed by Sorokin in his vitriolic book "Fads and foibles in modern sociology and related sciences" (Regnery, 1957): lack of modesty, lack of clarity and misuse of concepts from the physical sciences.

b. There is apparent in some discussions a lack of elementary training in philosophy as, for instance, when structure and function are confused or more seriously when the word "system" is *simultaneously* used in at least three distinct meanings: *1.* an interrelationship between constituents of a cell, organ, individual, or society; *2.* a model of such a relationship; *3.* a general theory about such models.

c. Grinker's able summaries after each presentation do not succeed in pulling together what are essentially no more than highly intelligent conversations.

d. There is frequently a display of "cultural" snobbery as when currently fashionable terms such as "transactional" are used without elaboration or clarification.

e. In spite of the careful editing there remains much repetition, partly due to the fact that the reader gets in one volume what those attending the conferences got in 4 widely spaced installments.

Some of the criticisms are patently unjust because they confuse intention and result. It can hardly be expected that a group of individuals meeting only for brief conferences will produce philosophically sophisticated and technically complicated supertheories *ad hoc.* It will take prolonged efforts and much ingenuity and enthusiasm to succeed in such a task. Most of these men are very busy. It may be necessary to create special niches for individuals who have the inclination and show promise of developing the ability to compare and integrate concepts from different disciplines. Certainly philosophy and logic should be part of the training of such individuals. In the meantime interdisciplinary groups such as this one can make a good start in clearing the ground of dead wood and rotten stumps.

The self-criticism, common sense and contagious enthusiasm of this group is evident. A new quarterly journal "Behavioral Science" and a new "Society for the Advancement of General Systems Theory" are continuing the search.

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Interpersonal Diagnosis of Personality. By TIMOTHY LEARY. xix + 518 pp. New York: Ronald Press, 1957. $12.00.

In our modern "dynamic" age the simple question, How is personality to be adequately described?, hides a complex web of problems. The need for an evaluation of unconscious motivating forces on the one hand and the potentiality for quantification on the other has been the focus of much discussion. The system of description presented in this book offers a constructive approach to these problems. It is a multi-level system of description, including the levels of concrete behavior, conscious perceptions, and unconscious forces. The data obtained is analyzable qualitatively as well as by standard statistical techniques. Levels are defined separately; the uni-level ratings are then fitted into a pattern which reflects the interplay among the levels.

It should be noted that the Interpersonal Diagnostic System is "diagnostic" because it grew out of a clinical situation. The book, though concerned with interpersonal behavior "primarily as expressed and observed in the psychotherapeutic setting," presents a general system of description designed to be applied to the description of people in any and all settings.

The book is divided into 5 parts. Part I, entitled, "Some Basic Assumptions about Personality Theory," is an interesting, but somewhat loose and over-extended presentation of the major theoretical sources of the System, principally the work of Harry Stack Sullivan. Leary refers to his approach as "dynamic behaviorism" and at one point defines, "The interpersonal factors of personality are those conscious or unconscious processes which people use to deal with others and to assess others and themselves in relation to others. The aim of interpersonal machinery of personality is to ward off anxiety and preserve self-esteem."

Part II, entitled, "The Interpersonal Dimension of Personality: Variables, Levels and Diagnostic Categories," presents 5 "levels of personality," each level defined in terms of operations which produce the pertinent data. To this reviewer this section contains the most significant theoretical-functional contribution.

Part III presents "Indices of Variability," by which conflict is measured through analysis of interlevel discrepancies. The variability indices are not described in detail nor is their "validation and clinical applicability" included in the book.

Part IV and V offer concrete illustrations of the application of the System: first, its use in clinical diagnosis; and second, its application to hospitalized psychotics, psychosomatic types, group dynamics in industrial groups and interpersonal dynamics in group psychotherapy.

The use of operationally defined "levels of personality," measured using the same frame of reference, seems to be the most exciting aspect of the system. The three most important levels are:

I The level of Public Communication, which consists of the overt behavior of the individual as rated by others. (In such situations where "Others" are not available Leary has applied the MMPI to obtain Level I descriptions.)

II The level of Conscious Communication, which consists of the subject's reported percepts of himself and his interpersonal world.

III The level of Private Communication, which abstracts from the projective, indirect fantasy productions of a subject an interpersonal self-image and a symbolic world of "others."

Eight generic ways of interaction have been isolated for use as the overall variable system. They are: (1) Managerial-Autocratic, (2) Competitive-Narcissistic, (3) Aggressive-Sadistic, (4) Rebellious-Distrustful, (5) Self-Effacing-Masochistic, (6) Docile-Dependent, (7) Cooperative-Overconventional, and (8) Responsible-Hypernormal. These are organized in a circular continuum, in which all the interpersonal variables are systematically related to each other, and of which the major axes are love-hostility and dominance-submission. Any sample or group of samples of interpersonal behavior can be classified through the use of this circular matrix.

A simplified illustration of the system's use and potentiality may be offered here. A person may be described as extremely dominant by those who know him and may see himself in the same way, whereas his fantasy heroes are largely passive. The multi-level numerical description of this individual would be 1-1-5, and this can be presented graphically as well on the basic circle; the ease of classifying people by the use of this numerical diagnostic technique is striking. Qualitatively, the conflict between the person's conscious and unconscious views of himself is extreme. Additionally, he is consciously aware of how he is seen by others.

The presentation of the system is functional. The data for Levels I and II are obtained by the use of the Interpersonal Adjective Checklist and for Level III from tests of fantasy such as the TAT. This data is easily obtained; test administration, scoring and rating can be done by non-professional, well trained technicians. The book, with the addition of a manual entitled, "Multilevel Measurement of Interpersonal Behavior," contain all necessary instructions for the use of the system and much data is offered on varied groups that have been studied at the Kaiser Foundation.

Interpersonal Diagnosis of Personality offers a rich, promising contribution to the area of the description of people. One is impressed with the simplicity and freshness of its approach. But, unfortunately, such praise must be qualified. The system, though brilliant on its surface, often has too weak a foundation. Some parts are supported by substantial research while others are based on very little. The offering in book form of the Interpersonal Diagnostic System seems too ambitious and too early. However, the system cannot fail to be of use to scientists concerned with problems of description and measurement of personality.

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Manifest Structure Analysis. By Frank M. duMas. Pp. ix + 193. Missoula, Montana: Montana State University Press, 1955. $6.00.

The author has set forth ambitiously conceived scaling objectives but his approach is at once hasty, unclear, and sorely lacking in empirical support. The list of topics is extensive, but the treatment has that once-over-lightly touch. What is most discouraging, perhaps, is that the sweeping claims made are certain to attract attention and interest of research workers in fields and disciplines for which the methods and assumptions of MSA are inadequate. Less preoccupation with the search for a scaling panacea and more concern with presenting strong evidence would make the author's position more tenable and his contribution more useful.

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BOOK NOTICES

THE PERSON BEHIND THE DISEASE. By Julius Bauer. vii + 136 pp. Grune and Stratton, New York, 1956. $3.50. The objective of this book is to elaborate on the holistic concept of the person in health and disease, based on the one hand on the practical appreciation of psychosomatic unity and, on the other hand, on the uniqueness of the individual, with its genetic basis.

VERTEBRATES OF THE UNITED STATES. By W. Frank Blair, Albert P. Blair, Pierce Brodkorb, Fred R. Cagle, and George A. Moore. ix + 819 pp. McGraw-Hill, New York, 1957. $12.00. The principal aim of this usable manual is "to facilitate the identification of all known U. S. vertebrates through the assembling of taxanomic keys, check lists, descriptions and ranges." There is an introduction (30 pp.) and a glossary.

REPORT OF THE MEDICAL RESEARCH COUNCIL FOR THE YEAR 1955-1956. 270 pp. British Information Services, New York, 1957. $1.50. Informative survey of the manifold activities carried under the Council's sponsorship in clinical and basic medical sciences.

SYMPOSIUM ON NUTRITION AND BEHAVIOR. Edited by Josef Brožek. 124 pp. The National Vitamin Foundation, Inc., New York, 1957. $2.50. An interdisciplinary survey consisting of sixteen papers, plus introductory statements and an epilogue, divided into four sections: Impact of diet on behavior, Hunger and appetite, Food appraisal and acceptance by man, and Satiety and weight control.

WILLIAM HARVEY. HIS LIFE AND TIMES; HIS DISCOVERIES; HIS METHODS. By Louis Chauvois. (Tr. from French). 271 pp. Philosophical Library, New York, 1957. $7.50. "Compared with experiment, all the rest is metaphysics and dialectic—smoke and inanity." This illustrates well the author's lively style and is a testimony of his high regard for Harvey's scientific method.

GENETIC MECHANISMS: STRUCTURE AND FUNCTION. Cold Spring Harbor Symposia on Quantitative Biology, Vol. 21. xviii + 392 pp. Biological Laboratory, Cold Spring Harbor, New York, 1956. $8.00. The primary objective of the symposium was bridging of the gap separating genetics and experimental embryology. The problem of genetic mechanisms was considered at the clinical, genic, chromosomal, cellular and developmental level.

INTRODUCTION TO STATISTICAL ANALYSIS. By Wilfrid J. Dixon and Frank J. Massey, Jr. xiii + 488 pp. McGraw-Hill, New York, 1957. $6.00. Second revised edition of a substantial textbook designed for a basic course in statistics presented as a general theory and practice of testing hypotheses through the evaluation of numerical observations.

MEDICAL RADIATION BIOLOGY. By Friedrich Ellinger. xxxiv + 945 pp. Charles C. Thomas, Springfield, Illinois, 1957. $20.00. The field, considered as the younger sister of pharmacology, is presented in four sections devoted to the fundamental considerations of the biological effects of radiant energy (104 pp.), ionizing radiations (606 pp.), ultraviolet radiation (65 pp.) and visible light and infrared radiation (23 pp.). 4600 references.

GROWTH AND DEVELOPMENT OF DENTAL AND SKELETAL TISSUE—CLINICAL AND BIOLOGICAL ASPECTS. Edited by Samuel J. Fomon. 80 pp. Ross Laboratories, Columbus, Ohio, 1956. No price. This report of the 17th Ross Pediatric Research Conference considers genetic, nutritional and endocrine factors in the "hard tissues."

SURVEY OF BIOLOGICAL PROGRESS. Vol. III. Edited by Bentley Glass. 332 pp. Academic Press, New York, 1957. $7.50. The selected vistas of the biological panorama include, among other topics, embryological concepts in the 20th century, animal genetics, chemoreception in insects, and mechanism of hormonal action.

PERSONAL CHARACTER AND CULTURAL MILIEU. Edited by Douglas G. Haring. xi + 834 pp. Syracuse University Press, Syracuse, New York, 1956. $7.50. Third, revised edition of papers by anthropologists on culturally fostered patterns of personal character. There is an introductory chapter by the editor and 5 contributions on how an anthropologist works in the field.

THE CONCEPT OF DEVELOPMENT. Edited by Dale B. Harris. x + 287 pp. University of Minnesota Press, Minneapolis, 1957. $4.75. The topic is examined by 17 authors representing a wide array of disciplines from philosophy of science through biology, psychology, and sociology to the applications in pediatrics, psychopathology, social work and education.

ALCOHOLISM, BASIC ASPECTS AND TREATMENT. Edited by Harold E. Himwich. viii + 212 pp. American Association for the Advancement of Science, Washington, D. C., 1957. $5.75. Proceedings of a multi-disciplinary symposium concerned both with the basic aspects and treatment.

TRANQUILIZING DRUGS. Edited by Harold E. Himwich. viii + 197 pp. American Association for the Advancement of Science, Washington, D. C., 1957. $5.00. These are boom days for "psychopharmacology," the study of the mode of action of drugs and the effectiveness of central stimulants, hallucinogens and—not the least of them—the tranquilizers. The current volume is concerned with the electrophysiological and metabolic analysis of their action and therapeutic uses.

HORMONES, BRAIN FUNCTION, AND BEHAVIOR. Edited by Hudson Hoagland. viii + 257 pp. Academic Press, New York, 1957. $7.00. The proceedings of a conference on neuroendocrinology, held in May, 1956, reflect the growing interest in the biochemical determinants of conduct. The 12 papers deal, from this point of view, with steroid and sex hormones, serotonin and the thyroid hormones.

A DICTIONARY OF SCIENTIFIC TERMS. Edited by J. H. Kenneth. xvi + 532 pp. D. Van Nostrand, Princeton, New Jersey, 1957. $12.50. A well established member of the Van Nostrand family of scientific dictionaries and one-volume encyclopedias. Gives pronunciation, derivation and definition of some 14,000 terms used in the biological sciences.

HORMONAL REGULATION OF ENERGY METABOLISM. Edited by Laurance W. Kinsell. xiii + 242 pp. Charles C. Thomas, Springfield, Illinois, 1957. There are 8 papers by outstanding workers in the field, including a communication on pituitary growth hormone, and extended discussions.

THE PHYSICAL GROWTH OF CHILDREN: AN APPRAISAL OF STUDIES 1950-1955. By Wilton Marion Krogman. iii + 91 pp. Child Development Publications of the Society for Research in Child Development, Purdue University, Lafayette, Indiana, 1956. No price indicated. An indispensable *vademecum* presenting 1) a digest of data, 2) a critique of trends and goals and 3) a fairly omnivorous bibliography.

PSYCHOLOGY, PSYCHIATRY AND THE PUBLIC INTEREST. Edited by Maurice H. Krout. xv + 217 pp. University of Minnesota Press, Minneapolis, 1956. $4.00. Assembly of papers, largely prepared especially for this volume, and of statements of policy dealing with the role of clinical psychology and its relation to psychiatry.

THE CONTROL OF THE CIRCULATION OF THE BLOOD: SUPPLEMENTAL VOLUME. By various authors. Arranged by R. J. S. McDowall. vii + 257 pp. Wm. Dawson, London, 1956. $9.00. The supplement to a reprint of McDowall's 1938 volume consists of 12 articles, by different authors, reflecting the major advances made in the last 17 years (incl. cerebral circulation, muscular exercise, and lack of oxygen.)

THE NATURE AND TRANSMISSION OF THE GENETIC AND CULTURAL CHARACTERISTICS OF HUMAN POPULATIONS. 143 pp. Milbank Memorial Fund, New York, 1957. $1.00. The papers presented at the 1956 Annual Conference of the Fund fall into three groups dealing with 1) Biological and cultural factors in human heredity, 2) Evaluation of population characteristics (personality and measured intelligence, psychiatric symptoms, fertility), and 3) genetic bases of behavior and mental disorders.

EXPERIMENTAL PSYCHOLOGY AND OTHER ESSAYS. By I. P. Pavlov. 653 pp. Philosophical Library, New York, 1957. $7.50. A biography by Kh. S. Koshtoyants and Pavlov's brief autobiography are followed by papers covering all the major aspects of his work. It is good to have them available in English, but it should be noted that only a small fraction deals with "experimental psychology." And who are the mysterious translators and editors?

INDIVIDUAL DIFFERENCES IN NIGHT-VISION EFFICIENCY. By M. H. Pirenne, F. H. C. Marriott and E. F. O'Doherty. 83 pp. British Information Services, New York, 1957. $1.44. The principal aim of the study was to assess sensory acuity and perceptual efficiency by means of specialized visual tests administered at low illuminations to dark adapted subjects.

FORSCHER UND WISSENSCHAFTLER IM HEUTIGEN EUROPA: ERFORSCHER DES LEBENS. (Research Workers and Scientists in Today's Europe: Students of Life). Edited by Hans Schwerte and Wilhelm Spengler. 339 pp. Gerhard Stalling, Oldenburg, 1955. DM 16.80. The fourth volume of the important biographical, interpretative series "Gestalter unserer Zeit" (Makers of

Our Times) is devoted to medical scientists, biologists and anthropologists (P. M. Boule—fossil man, S. K. Mollison—human evolution, E. Fisher—human biology, E. von Eickstedt—comparative human biology, R. Biasuti—anthropogeography).

ORGANIZATION OF THE CEREBRAL CORTEX. By D. A. Sholl. xvi + 125 pp. John Wiley, New York, 1956. $4.25. A unified view of recent work carried out by anatomists, clinicians, physiologists and psychologists. The author favors a theory of cortical organization employing models based on the concept of probability and discussed in statistical terms.

BIOCHEMICAL DISORDERS IN HUMAN DISEASE. Edited by R. H. S. Thompson and E. J. King. xiv + 843 pp. Academic Press, New York, 1957. $12.60. For many disorders pathological description and analysis is passing from the stage of histology to that of biochemistry. In this collaborative work (31 contributors) we find assembled and interpreted the known facts in this field.

DICCIONARIO DE PSICOLOGIA. Edited by Howard C. Warren. Translated & Revised by E. Imaz, A. Alatorre and L. Alaminos. xvi + 383 pp. Fondo de Cultura Economica, Mexico, 1956. $3.50. A translation of a dictionary first published in English, with the addition of biographical data that are not always reliable or up to date.

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INFORMATION FOR CONTRIBUTORS

Human Biology, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

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